INSTITUT DE RECHERCHE
D'HYDRO-QUÉBEC

AFFAIRES
INTERNATIONALES

TECHNOLOGIE

REPORT OF ACTIVITIES 1989

HYDRO-QUÉBEC

TAI

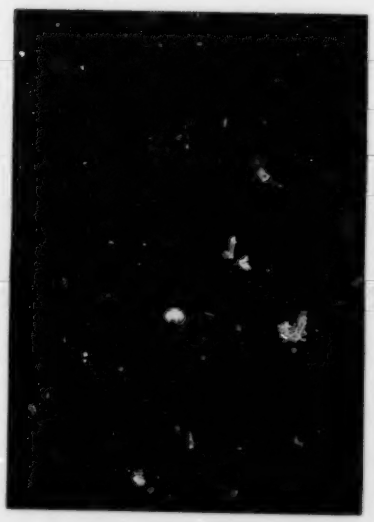
Hydro-Québec's Groupe Technologie, Affaires internationales et IREQ has a mandate to conduct research, tests and development and demonstration work in the areas of power generation, transmission and distribution, together with industrial applications of electricity.

91-02692/

Its activities cover electrical apparatus, cables, overhead lines, internal and external insulation, mechanical engineering, electronics, materials chemistry and technology, power system simulation and analysis, and industrial electrotechnologies. Alone or with outside partners, TAI markets some of the products developed at its laboratories and is responsible for planning Hydro-Québec's future technological development. It also makes the utility's expertise available to some 25 countries all over the world through its subsidiary, Hydro-Québec International.

TAI has a staff of 572 permanent employees and about 100 temporary employees, as well as personnel at its subsidiaries. It operates major research and testing facilities, including a high-voltage and a high-power laboratory for testing extra-high-voltage power systems and electrical apparatus, a power system study and simulation centre as well as laboratories specializing in electrochemical and electrical technologies, LTEE.

In addition to work for Hydro-Québec, TAI undertakes research and testing for external clients.



The new high-voltage underground-cable test area was commissioned at the high-voltage laboratory towards the end of 1989. Testing is now in progress on three ±500-kV DC cable prototypes. The tests will take close to 12 months and the results will serve to select the cable to be used for the St. Lawrence River crossing.

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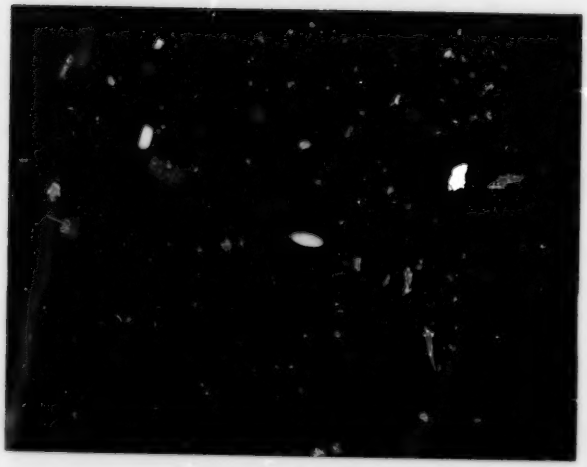

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MESSAGE FROM THE EXECUTIVE VICE PRESIDENT

Among the multiple activities and achievements of the past year, the examples that spring to mind are the tests on underground high-voltage cables, the development of a nonfragmenting surge arrester and the testing of a compact robot for hydraulic turbine repair. Other highlights include the study of hydrogen production and transportation to Europe, multinational power system interconnections in Africa and the Arab Peninsula, the marketing of different types of software, and the development of integrated dual-energy heating systems.

Whether for Hydro-Québec or for outside organizations, each project bears witness to our attentive response to needs and the rewarding cooperation we enjoy with partners in Québec and abroad. And I take advantage of this opportunity to remind our clientèle of the quality of the products the competent and creative men and women on our staff make available. Their contribution plays a vital role in our constant effort to maintain the excellence of our work. My sincere thanks go to them all.

I see that TAI has entered a period of maturity. The organization structures introduced a short time ago have proven sound and meet our needs. The technology planning process has now been implemented and the updating mechanisms are already in place. Our new professional consultant-client approach is now well established and our personnel has had the suitable training for incorporating this approach into their work.

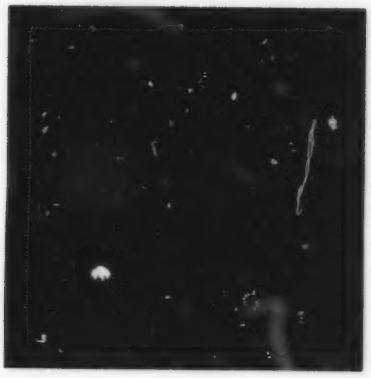
I am proud of our accomplishments. I am equally confident that, together with our clients, partners and other members of TAI, we will go on to even greater achievements in future.

Maurice Huppé
Executive Vice President
Technology, International Affairs
and IREQ

1989 HIGHLIGHTS

TAI personnel carried out some 500 research and development projects during the year and fulfilled over 300 testing contracts. Over $100 million was allocated to the pursuit of Hydro-Québec's technological objectives within TAI. Nearly $14 million was added to the total operating budget by other Hydro-Québec departments for R&D or testing on their behalf. Government agencies, electrical utilities and industry contributed a further $12 million. Lastly, a sum of $35 million was allocated for capital investments.

In addition to pursuing corporate objectives, TAI is exporting its know-how to over 25 different countries through the intermediary of Hydro-Quebec International.



NEW FACILITIES

Construction began or was completed on major new research and testing facilities this year. First the high-voltage underground-cable test facility was commissioned during the summer in readiness for tests on the ±500-kV DC cable prototypes for the future under-river crossing for the James Bay – New England line. Located close to the high-voltage laboratory, to which it belongs, the 20,000-m² test area allows simultaneous testing of three cables in separate duct banks. The construction cost amounts to $13 million.

Work began on another new facility in 1989: an electric and magnetic field demonstration centre. Covering a surface area of 500 m², the centre will offer the public a state-of-the- art overview of the biological effects of electric and magnetic fields and provide answers to current concerns in this area.

Work will soon begin on the construction of a new mechanical test line in the vicinity of IREQ for studies of the effects of light winds on overhead transmission line conductors. Meanwhile, the power system study and simulation centre is nearing completion as equipment is installed. The high-voltage laboratory has recently received a new addition in the form of a hoisting bar for handling heavy equipment, which should facilitate testing.

TRANSMISSION

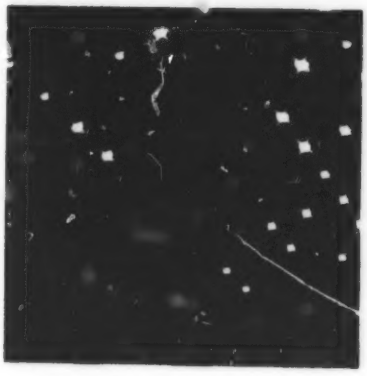
Tests were performed throughout the year, both in the high-voltage laboratory and at the new outdoor testing facility, on the ±500-kV DC cable prototypes supplied by three different manufacturers. Testing should continue until the end of 1990 and the results will be used to select the underground cable for the St. Lawrence river crossing of the line linking James Bay to New England. Meanwhile, the low-temperature circuit breaker developed by a team of IREQ and GEC Alsthom Énergie specialists went into industrial production this year and two units are scheduled for installation on Hydro-Québec's power system early in 1990.

A study of optical fibres incorporated into an overhead ground wire was performed on IREQ's mechanical test line. Also, a simulator study of the effects of implementing series compensation was pursued throughout the year along with tests on the protection relays that will be needed. The simulator was also used to study problems related to the Châteauguay interconnection between the Québec and the American systems; a number of solutions were proposed.

In another area, a new version of the harmonic-analysis program was developed together with several expert systems both for apparatus diagnostics and for substation design. New interconnection technologies such as the asynchronous connection device were devised and DC current penetration into AC systems was studied, especially in terms of geomagnetic storms.

Several measuring systems were developed in 1989 in relation to lightning currents, relay evaluation, automatic controls, cable sleeve misalignment and the voltage phase angle. An analysis of the performance of new wall bushings was analysed and several expert appraisals were made of the quality of welded conductor assemblies.

With regard to overhead lines, work continued on various investigations into the effects of electric fields and a field exposure chamber was designed and built. Work began on a project on the effect of freezing rain and snow on transmission line insulation while the project on the effect of forest fires continued to mark progress. Specialists in mechanics completed a study on low-sag conductors and developed models for calculating conductor and conductor-spacer-damper system self-damping under eolian-vibration conditions. The high-voltage and high-power laboratories performed major tests on underground cables, wall bushings, converter transformers, distribution surge arresters, fibre optics, insulators and rapid-transit systems. Lastly, it is worth mentioning that Hydro-Québec and ASEA Brown Boveri have created a new centre for research and development in the power transmission field.



Generation

The first highlight to be mentioned with respect to generation-related activities is that the compact robot designed to repair damage due to cavitation successfully performed its first tasks at Hydro-Québec during the summer. In addition, an analytical model of hydraulic turbines (MATH) was developed while work continued on research into the detection of erosive cavitation using the acoustic-signature approach. Other monitoring and protection systems were also investigated in a number of major studies: the final prototype for measuring vibration on stator windings was completed, a digital protection relay for generators was developed and the RUPA digital relay system was evaluated in the field. Meanwhile, work continued on data acquisition and storage in the SUPER generating-station monitoring project and a complementary project was initiated on the monitoring of collectors.

IREQ specialists also contributed to a study of steels, the analysis of cracks in penstocks and an investigation into the materials and techniques used for repairing concrete structures at generating stations.

In the area of generating systems, various computer programs have been developed both for yearly planning purposes and for evaluating the performance of interconnected power systems while final touches were put to the modeling of a hydroelectric facility.

Meanwhile, research continued on the development of a control and regulation system for wind turbine-diesel generator combinations with no energy storage and with a high penetration level; this work forms part of a study on the means of supplying electricity to remote regions. The possibility of using fuel cells for this purpose was also explored. Lastly, analyses of water in the circuits of several nuclear power plants across Canada were performed during the year.

DISTRIBUTION

Development of a nonfragmenting surge arrester was completed in 1989 and some 500 units have been built; they will be installed on Hydro-Québec's distribution system for certification. Amorphous-steel specialists, for their part, are developing technologies that will allow this material to be employed in the construction of magnetic circuits for transformers.

Quality of customer service was the focus of various studies dealing with the power quality factor and the evaluation and interpretation of disturbances on the distribution system. Studies were also conducted on means to enhance safety in underground distribution systems exposed to fault arcs. Meanwhile, a number of new modules were added to distribution system planning software.

Work continued on an analysis of transformer vault corrosion, together with the remedial measures, and on a study of copper-aluminum connectors in a saline environment. An investigation has begun on the environmental diffusion mechanisms of pentachlorophenol, a preservative used for wood poles on the distribution system

With regard to extruded cables, progress was made in the studies of dielectric breakdown, oxidation and water treeing, and a cable-aging model was developed.

INDUSTRIAL APPLICATIONS OF ELECTRICITY

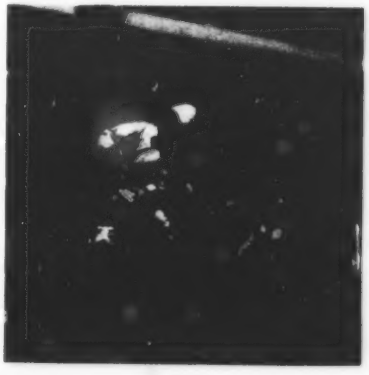
Many projects were undertaken at the electrochemical and electrical technologies laboratory in 1989 in fulfilment of LTEE's mandate to develop and demonstrate new industrial processes that use electricity as their primary source of energy. Special mention might be made of the development of an integrated dual-energy heating system, the installation of prototype heat pumps with a nonelectric back-up (PACANE), use of a 150-kW plasma torch for surface treatment of different materials, production of ethylene glycol by electrosynthesis and electrocoagulation of alfalfa.

Several drying and heating devices were acquired during the year, making LTEE better equipped than ever to meet the needs of companies wishing to develop and incorporate new electrotechnologies in their industrial processes.

MATERIALS, TEST TECHNIQUES AND MEASURING DEVICES

Development work on a puncture detection device for high-voltage line insulators led to the production of a commercial prototype this year. Meanwhile, in the context of the HVDC cable test program, a system for measuring the temperature of energized cables has been developed. Work was pursued also on the design of a device for analysing the leakage current on the surface of insulators while a joint project between Hydro-Québec and the École Polytechnique de Montréal was launched to study microwave drying for bushings.

The past year saw the development of techniques for the detection and analysis of methylmercury in water stored in hydroelectric reservoirs. Shunts for testing generators at the power plant have also been developed, in addition to a high-speed data acquisition system. Lastly, work continued on the expert evaluation of insulating oils used in electrical apparatus.



Development projects

Under an agreement between the Québec government and the Commission of European Communities, Hydro-Québec has undertaken a feasibility study on the production, intercontinental transportation and utilization of electrolytic hydrogen produced in Québec. In the field of polmer electrolyte (ACEP) batteries, performance optimization studies continue and negotiations are under way with a view to creating a joint venture for research, development and commercialization of this technology.

In other areas, specialists are installing a microcomputer-controlled system for automation of power system management functions at a Hydro-Québec distribution control centre. Development and implementation of expert systems are marking good progress and, lastly, a laboratory prototype has been developed for the treatment of cystic fibrosis.

Long-term projects

Activities related to the superconductivity project in 1989 were aimed mainly at improving the ceramics manufacturing processes in order to obtain superconducting materials with a higher current density. As for nuclear fusion, the research team took advantage of the tokamak being dismantled for the installation of new internal components to perform a detailed analysis of the results yielded by the first test series and to improve the performance of the various diagnostics for which it is responsible. Two members of the research team have been seconded to Europe to take part in the multinational ITER project, which involves the design and construction of a fusion reactor.

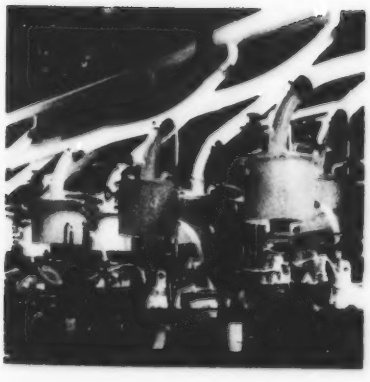
Work continues in the field of telerobotics, with the main focus this year on the development of a control system adapted to a telerobotics context. A project on the catalytic conversion of methane was completed.

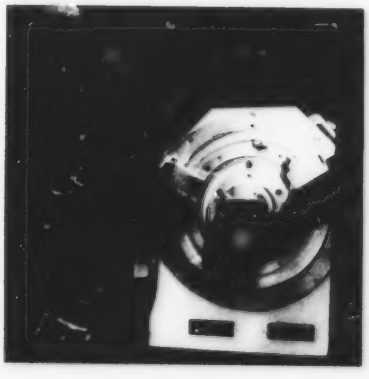
Marketing

Several marketing agreements were signed in 1989 for both the manufacture and the marketing of products developed in-house. Among others, mention might be made of a software marketing agreement with Cyme International, a Hydro-Québec subsidiary, and a similar agreement with Strateck Technologies covering their central-computer control software MECO. Another agreement was signed with Roctest for the marketing of a device designed to measure and analyse vibration on overhead conductors. Lastly, agreements were signed with Pyradia and Intek in relation to high-power-density resistances and with Lyster Industries for spacer-damper systems.

Technology planning

Following publication of the Technology Plan 1989-1991 last March, the remainder of the year was devoted to consolidating the Plan in terms of the utility's ever-changing priorities and needs and to implementing follow-up mechanisms.





TAI'S ORGANIZATION

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Alain Brosseau
Vice President

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Josée Lacasse
Director

TECHNOLOGY PLANNING

Following publication of the Technology Plan 1989-1991 last March, the remainder of the year was devoted to consolidating the Plan in terms of the utility's ever-changing priorities and needs and to implementing follow-up mechanisms.

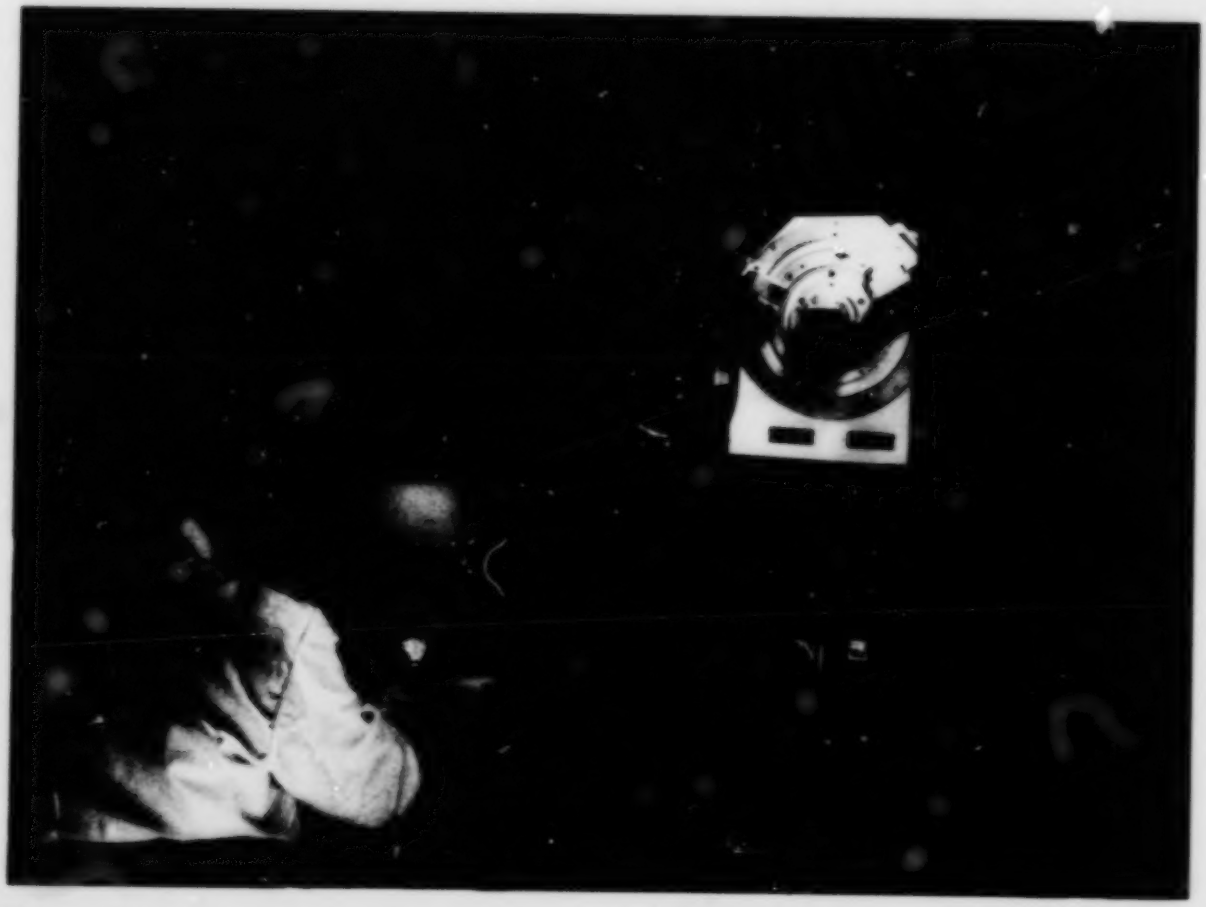
Technology planning has a two-fold objective: to define Hydro-Québec's technological options and to prepare for the utility's future in terms of these options. The activities affect all aspects of research, development, demonstration and testing as well as long-term research projects, the development of products and facilities, and the marketing of those products.

The planning process introduced two years ago covers the following strategic fields: generation, transmission, distribution and utilization of electricity. Drawing its inspiration from the utility's management philosophy, it identifies four clear goals:

- promote a corporate view of technology;
- first meet Hydro-Québec's needs;
- incorporate technology planning into every activity forming part of the utility's management cycle;
- encourage company-wide dialogue.

The cornerstone in the technology planning process is the forum created in 1988 which draws together 150 representatives - middle management, experts, researchers, engineers and specialists - from the various sectors of activity at Hydro-Québec.

This forum provides an opportunity for departments throughout the utility, whether they are the suppliers or beneficiaries of technological services, to participate on a continuing basis in the preparation of the Technology Plan. The forum also welcomes representatives from departments with a corporate mission, such as corporate planning specialists, who bring clarity to the issues discussed. In March 1989, on the strength of the forum's decisions, Hydro-Québec was able to publish its first integrated Technology Plan for the years 1989 to 1991.



The Plan is not limited to describing the future activities of TAI but establishes a comprehensive plan for all Hydro-Québec activities that could be described as technological. To facilitate the planning of all these activities and simplify the budgeting, the databank of R&D projects has been completely restructured.

The technology planning activities performed in 1989 were oriented toward consolidating the three-year plan in terms of the utility's constantly evolving needs and priorities on the one hand, and reinforcing the professional consultant-client approach on the other. Hydro-Québec's commitment to this new operating mode is reflected in the method it now applies to award work contracts. This method defines the terms for awarding and executing TAI's research and development projects requested by other Hydro-Québec departments. It is also designed to promote any products developed in the course of such projects and to maximize their benefits and spinoffs.

To achieve this goal, the technology planning process has been synchronized with budget planning. A new program of activities drawn up for 1991 has thus served as the basis for the corporate budgets as well as the individual budgets of all departments concerned.

A technician analyses the crystal phases of a sample in the x-ray diffractometer.

The foregoing measures have allowed Hydro-Québec to decentralize R&D, demonstration and testing budgets among the departments requesting the work. Already, 54.7% of the technology budget was decentralized in 1989, and it is expected that 76.8% of the budgets will be in the hands of these departments in 1990. It should be mentioned, too, that the funds for service quality, energy efficiency and adaptation to demand are expected to rise from 58.3% in 1989 to 70.4% in 1990. The volume of work anticipated for 1990 is so great that $10 million has been added to the operating budget.

The past year saw work begin on the design of a follow-up mechanism, which will be implemented in 1990, to ascertain the degree to which the various strategies defined in the Plan effectively meet stated objectives and to propose remedial measures, where appropriate.

Meanwhile, discussions began on the means of establishing indicators for evaluating the performance of technological activities not only in terms of the utility's optimum economic viability, but also in relation to other management concerns – service quality, occupational health and safety, environmental protection, and the social and economic development of Québec society. If these indicators are sufficiently accurate, it will be possible even at the planning stage to better define the expected as well as the real impact of the activities planned, and, also, to determine priorities and the pertinence of decisions so that funds can be allocated appropriately.

In collaboration with the Centre de recherche industrielle du Québec (CRIQ), Ontario Hydro and other organizations, a prospective network has been established to gather data on all technological achievements not only at Hydro-Québec but at research centres in Canada and abroad. Exploring technological avenues is vital to planning, since new or emerging technologies may not only influence the quality and cost of the solutions sought but also alter the very needs that generate the research.

The technology planning group has played a role in several large-scale activities under way at IREQ – including development and long-term projects – in order to define its position and establish a corporate strategy. Its contribution has proven especially useful in such areas as robotics and superconductivity.

As in the past, links have been strengthened with various outside organizations through participation in the coordination of many projets. Mention might be made, among others, of the Ministère de l'énergie et des ressources, the parliamentary Committee on Labor and the Economy, a number of Québec universities and, outside the province, Ontario Hydro, Manitoba Hydro and Manitoba HVDC Research Centre.

GENERATION

Generation-related activities were as varied as they were numerous in 1989. With regard to hydraulic turbines, mention should be made of the compact robot designed to repair damage due to cavitation, the development of an analytical model of hydraulic turbines and further research into the detection of erosive cavitation using the acoustic-signature approach. Several monitoring and protection systems were also investigated: a device for measuring vibration on stator windings, a digital protection relay for generators, monitoring instruments for collectors and turbine generator units.

In the area of power-system operation, various computer programs have been developed both for yearly planning purposes and for evaluating the performance of interconnected power systems, while final touches were put to the modeling of a hydroelectric facility.

Research continued on wind turbine-diesel generator combinations for supplying electricity to remote regions, and the possibility of using fuel cells for this purpose was explored. Lastly, analyses of water in the circuits of several nuclear power plants across Canada were performed during the year.

ROBOTIZATION OF ON-SITE TURBINE MAINTENANCE

The second phase in the on-site maintenance robotization project for cavitation-damaged turbine runners drew to an end this year. The last test, performed jointly with Ontario Hydro, was on a Kaplan blade at Carillon generating station. The test demonstrated that, with the help of the prototype compact robot, an operator can restore the blade profile and maintain a safe working distance throughout the three operations of grinding, welding and polishing. The quality of the profile depends partly on the operator's ability to program the various tasks to be performed, although programming has been greatly simplified by a user-friendly man-machine interface and by the contour-programming technique developed at IREQ.

Hydrobot, the compact robot for on-site repair of turbine runners, performs gouging operations in a Kaplan turbine at Hydro-Québec's Carillon generating station.

The compact robot can repair the blades of Hydro-Québec's large hydraulic turbines, which account for some 20% of its generating facilities, but an even more compact smaller device now needs to be designed for smaller turbines. Furthermore, automatic task planning poses a problem because in small turbines much of the working space is taken up by the robot, making access particularly difficult. A self-programmable robot would significantly reduce the time devoted to task planning and eliminate an unpleasant job. At the request of the Vice-présidence Production, Transport et Distribution, technical design studies have now begun with a view to building a supercompact robot prototype which meets these requirements.

Technologie des matériaux
(Materials Technology)

GENERATION SIMULATION FOR ANNUAL PLANNING

A simulation program for improving Hydro-Québec's annual generation planning process was developed in 1989. A deterministic optimization model, NUMA version 3, run on the computer periodically in conjunction with the most probable inflow scenario for the coming year, is the principal tool used in this process.

With the new software, power system operation can be simulated according to principles similar to those of a stochastic model in that the inflows are taken into account only one week ahead. More specifically, the approach adopted by this simulation program is to solve different successive optimization subproblems, each covering one week and comprising a reward function for the final hydraulic condition of the system. The reward functions are derived from the data generated by the last computer run of the annual deterministic model and the multiannual aggregated stochastic model.

The new simulation tool enables Hydro-Québec to obtain detailed generation plans for a large number of equally probable inflow scenarios and then assess the probability of occurrence of various system phenomena such as spillage or load-shedding, for example. Decisions based on the deterministic model can then be adjusted, if necessary, according to the results obtained.

Lastly, the new simulation software prepares the groundwork for a future annual planning stochastic model with non-aggregated system representation.

Méthodes numériques
(Numerical Methods)

MODELING AND DIGITAL SIMULATION OF HYDROELECTRIC POWER PLANTS

Work is under way to develop a digital model of a hydroelectric power plant in an aim to optimize the performance of turbine-generator controls, which play a critical role in system operation. The first task is to study the water flow in conduits and turbines to better understand the phenomena that determine the dynamic behavior of a power plant.

The study would not be complete without considering the possibility of interactions between the dynamic behavior of the generating units and the DC link to which the power plant under study is connected. The following elements must therefore be represented:

- elasticity of the conduits, friction losses at the conduit walls and compressibility of the water;
- turbine losses under various operating conditions;
- the synchronous generator, its damping circuits and magnetic circuit saturation;
- the speed governor and voltage regulator of each unit;
- the DC link and its control systems.

Since the turbine is represented by an algebraic model, it is possible to study the effect of variations in the turbine parameters on the performance of the entire power plant. Another advantage is that most of the parameters of this model are derived from geometric data provided in the plant blueprints. The turbine modeling was validated using La Grande 2 data; the characteristics yielded by the model match those obtained experimentally with the required degree of accuracy.

The model used to simulate the hydraulic part of a power plant can also be applied to study the performance of a plant with long penstocks, a configuration which is planned for Brisay power plant, for example. In this case, the penstock elasticity and water compressibility are even more critical.

The project was requested by the Vice-présidence Production, Transport et Distribution.

Méthodes numériques
(Numerical Methods)

RELIABILITY EVALUATION FOR INTERCONNECTED POWER SYSTEMS

New software has been developed for determining the reliability (in terms of capacity) of a power plant forming part of an entire network of interconnected power systems. NEXION, as the software is called, uses a probabilistic calculation method. The method is based on a representation of the various power plants and the tie lines between them. Its main purpose is to evaluate loss-of-load probability, although it can also provide the reserve gain, among other results.

The power system planners responsible for drafting Hydro-Québec's Installations Plan intend to add NEXION to the tools it uses to establish the basis for sharing reserves with other systems connected to the Hydro-Québec grid, with the aid of a reliability criterion. Knowing these systems' potential contribution, the utility will then be able to reduce the amount of generating equipment that would otherwise be provided for in the Plan.

The same software was used in a Hydro-Québec International project involving the interconnection of power systems operated by Arab gulf states.

Méthodes numériques
(Numerical Methods)

ANALYSIS OF WATER IN THE CIRCUITS OF NUCLEAR POWER PLANTS

The last few years have witnessed the development of a series of leading-edge techniques for determining morpholine degradation products. Morpholine is a pH control agent used to minimize erosion-corrosion in the steam-water cycles of CANDU PHW and PWR nuclear power plants.

Developed by a team of chemists from the Service Chimie des matériaux and the Service Câbles et Isolants, these techniques were put to the test in spring 1989 in analytical studies for Gentilly 2 (Hydro-Québec) and Point Lepreau (New Brunswick Electric Power Commission). The chemical conditioning of the water at

Analysis of water samples from the thermal cycle of a nuclear power station by high-performance ionic chromatography.

these generating stations differs in many respects, as do some of the components of their thermal cycle. The analysis of morpholine and its decomposition products thus provided an opportunity to learn more about the chemistry of these systems.

In addition, various analyses were performed at Ontario Hydro's Bruce B generating station towards the end of the year. In an initial phase, the study aimed to establish the chemical conditions of a system that has never operated with morpholine while in a second phase the purpose was to determine the effect of morpholine injections. The data gathered in the course of these studies will be used in 1990 to compare the chemistry of the steam-water cycle of nuclear plants throughout Canada under a CANDU Owners Group contract.

Chimie des matériaux
(Materials Chemistry)

PENSTOCK INSPECTION AT BERSIMIS 2

Inspection of equipment that has experienced failure provides an opportunity both to determine the cause of the failure and to obtain further knowledge about such phenomena as the fatigue and strength of materials. It offers a means of improving design and construction methods and preventing similar failures.

In 1989, a crack over one metre long in the headrace canal of a generating unit upstream of the spherical valve at Bersimis 2 brought production to a complete halt. The upstream flange of the valve had been totally destroyed while the downstream flange and several connecting bolts were seriously damaged. Inspection revealed that the crack had started at an insertion bolt in the valve flange. Over the years, fatigue had slowly extended the crack which, by the time of the incident, had reached a critical stage.

Meanwhile, a large axisymmetrical crack had developed at the base of a weld on the headrace of the same generating unit. Since the insertion bolts used here are identical to those on other units at Bersimis 2, it was recommended that stability diagrams be used once the plant was put back into service. These diagrams serve to forecast the progression of faults so that any necessary repairs can be made during off-peak periods and the safety of employees at the generating station assured.

Before this procedure could be implemented, the research team had first to perform a finite-element analysis of the stress distribution around the valve and determine the fatigue properties and breaking strength of the 516 steel used.

Technique des matériaux
(Materials Technology)

DIGITAL PROTECTION SYSTEM FOR GENERATORS

The design of a new digital protection relay for generators, DIGLO, was completed in the course of 1989. The relay covers two functions: the global differential for the generator-transformer combination and the volt/hertz ratio at the generator output. Both cases involve three-phase protection systems, with measurements taken on each phase separately and the functions processed independently for each phase. A laboratory prototype of the new relay will soon be installed at Hydro-Québec's Carillon generating station.

DIGLO has just been added to a relay developed at IREQ in 1988. The earlier relay, RUPA, comprises seven protection functions, all offering the following advantages: reduced equipment costs, space savings, and a flexible, modular design making it adaptable to the protection of substations. Combination of the two relays has produced complete digital protection for generators.

Meantime, work continued on the evaluation of a RUPA relay installed some 12 months ago at Carillon generating station. Two problems arose, coincidentally: loss of the settings and false tripping of the stator differential protections. It was therefore resolved to check the settings continuously and to monitor the current input in order to detect any failure of the input circuits.

Électronique
(Electronics)

VIBRATION MEASUREMENT ON STATOR WINDINGS

The project involving the design of a vibration measuring device for stator windings has entered its last phase: the prototype is operational and will soon be delivered to the Direction Appareillage. The device measures the vibration level of a winding over a range from 2 to 200 μm rms. The vibration signals can also be reproduced in the form of a calibrated analogue signal (10 mV/μm) for more detailed analysis, for example, by a frequency analyser. Experimental measurement probes have now been permanently installed in six generators in Hydro-Québec's Manicouagan Region.

The vibration measuring device not only offers an excellent technical performance but is easy to connect and operate. Very compact, it is a portable tool that can be taken from one site to another by maintenance crews to gather information on generators equipped with experimental vibration transducers. Analysis of the results will provide the data needed to assess the efficiency of this method of monitoring the quality of the wedging system used for stator windings.

Électronique
(Electronics)

COLLECTOR WEAR MONITORING

At the request of apparatus specialists at Hydro-Québec, a project was launched during the past year to develop a method for monitoring the collectors of generators, in particular for the wear of carbon brushes and overheating of the collector rings or commutator segments. Various factors contribute to the early wear of carbon brushes: wrong settings, excessive pressure, poor ventilation, manufacturing flaws, etc. Wear, in turn, results in overheating of the collector rings, which can structurally damage the equipment. The monitoring method envisaged should limit damage and curtail the number of inspections, which involve shutdowns of at least 24 hours.

Several approaches have been explored and subjected to preliminary tests in the laboratory. One of these consisted in measuring the electromagnetic noise produced by worn brushes; this can be done either by direct contact or with an antenna. The second technique is to measure the temperature of the collector rings to detect hot spots caused by early wear of the brushes. Here again two approaches are planned: by direct contact or by infrared remote measurement.

Tests will be performed on in-service generating units during the next 12 months to determine whether brush wear can in fact be evaluated by measuring just one of the two parameters (temperature or electromagnetic disturbance) while at the same time determining the best measuring techniques and the required precision. A prototype detection system will then be developed and could eventually be incorporated into SUPER, Hydro-Québec's continuous monitoring system for generators.

Électronique
(Electronics)

WORK ON HYDRAULIC TURBINES

A long-term project began this year on the modeling required for the analysis of hydraulic turbines. The research team's specific objective is to develop various computer-based calculation and simulation tools to validate turbine design and study turbine-related problems. Activities to date include development of a quasi 3-D nonviscous flow model for turbine runners and initiation of various projects with the École polytechnique de Montréal and Canadian General Electric.

Meanwhile, work was pursued on the development of a computer-based continuous monitoring system for turbine-generators, SUPER, which began three years ago. Field experience with the prototype installed at Hydro-Québec's Rapide Blanc generating station has oriented more recent activities toward data acquisition and storage. 1990 will see the design of SUPER's diagnostic function, which will enable the system not only to detect anomalies but to inform station operators of their causes and to propose corrective measures.

Also in the monitoring field, efforts continued on acoustic-signature-based vibratory detection of erosive cavitation. Laboratory and field tests were performed.

In dam surveillance and maintenance, the research team undertook a project with Hydro-Québec's Manicouagan Region to build a test facility for developing grouting techniques for repairing cracks in concrete. Before the grouting studies themselves could begin, however, cracks as natural as possible had to be reproduced in concrete samples.

Mécanique
(Mechanical Engineering)

COMPARATIVE STUDY OF REPAIR MATERIALS FOR ERODED CONCRETE

A study was performed for the Canadian Electrical Association to compare the performance of different materials used to repair concrete hydraulic structures damaged by erosion.

Erosion is due mainly to climatic conditions and acid rain and is the cause of increasing problems in Hydro-Québec's facilities, some of which date back over 60 years. Enormous sums are spent on repairs using one or other of the many repair materials on the market. However, very little information is available on their performance.

The materials examined were cementitious grout, modified cement-based mortars with polymer additives, and epoxy mortars. Two properties were measured for preselection purposes: bond strength and erosion resistance. The materials selected were then subjected to various mechanical tests aimed at assessing their thermal expansion coefficient, thermal compatibility, nitrogen permeability, resistance to aging, weatherability, etc.

Of the 35 materials tested in the laboratory, 18 were eliminated at the preselection stage. Among the others, epoxy mortar yielded the best results, followed by cementitious grouts and polymer mortars containing styrene-butadiene rubber (SBR). Polymer mortars containing acrylics and copolymers both proved far less satisfactory. This classification is far from absolute, however, since performance of these materials depends on atmospheric conditions and on the nature and state of deterioration of the concrete.

It is now intended to propose a second project to the CEA which would involve Hydro-Québec operating personnel performing field tests on these materials. This research could eventually lead to the development of a new repair material better suited to the utility's needs.

Technologie des matériaux
(Materials Technology)

WIND TURBINE-DIESEL GENERATOR COMBINATION

Various studies on isolated power systems in the Ungava peninsula that are not connected to Hydro-Québec's main electrical grid reveal that wind turbines coupled to diesel generators could reduce operating costs. The most economical scenario seems to be the wind turbine-diesel generator combination with no storage and with a high penetration level (ratio of wind power to load). In this scenario, the wind turbine's installed capacity can equal or even exceed the system peak demand; in sufficiently strong winds, the diesel units could be shut down, safely leaving the wind turbines to supply the entire demand.

The aim of the current research program on combining wind turbines and diesel generators is to develop a control and regulation system that will allow a high penetration level to be achieved. An experimental demonstration of the diesel-wind combination was therefore undertaken in 1989 on the wind turbine at IREQ. The results of tests involving application of a variable load controlled by a frequency regulator confirmed that power system stability would be preserved even when sharp fluctuations in demand (0.2 p.u.) occur. Progress was made in the modeling of control systems for a wind-diesel generating station.

Work continued also on the Kuujjuaq project aimed at demonstrating the reliability of a wind turbine in Québec's northern regions. This 65-kW machine has now over 10,000 hours of operating time to its credit.

Lastly, computer models have been developed for fluid-structure calculations. Their main application so far has been for calculating nonstationary stresses on the 34-m experimental wind turbine developed by Sandia Laboratories in the United States.

Mécanique
(Mechanical Engineering)

FUEL CELLS FOR ISOLATED NETWORKS

In 1989 work was completed for the Canadian Electrical Association on a study of isolated networks with a view to using fuel cells as an energy source. First a list was drawn up of all remote sites in Canada and data was compiled on various pertinent factors such as installed capacity, generator output and fuel requirements. Two Québec sites, Blanc Sablon and Povungnituk, were selected for a more thorough evaluation using information supplied by the Montmorency Region.

In a second stage, a review of available technologies for converting fossil fuels into hydrogen to feed fuel cells was undertaken. It revealed that the diesel-reforming technology is not yet sufficiently advanced for this application. Moreover, no fuel cell of the appropriate size for most remote regions in Canada (i.e., less than 1 MW) is available yet.

In view of these results, the research team recommended that the CEA initiate a research program to develop catalysts for diesel reforming and to follow up on fuel cell technology. A full report on this study was submitted in February.

Chimie des matériaux
(Materials Chemistry)

The HVDC underground cable test program was pursued throughout the year. Meanwhile, a study was performed on the optical and mechanical aspects of optical fibres incorporated into the overhead ground wire of transmission lines, and the mechanical behavior of substation equipment was investigated. As far as simulation work is concerned, various studies were devoted to the implications of introducing series compensation on the Hydro-Québec power system.

In addition, lightning-current measuring systems were developed, the performance of new wall bushings for HVDC substations was analysed and methods for measuring cable sleeve misalignment were developed.

Projects under way on overhead lines include a number studies on the effects of electric fields; a field exposure chamber has been designed and built. The high-power and high-voltage laboratories, for their part, were the scene of many major tests during the year.

Finally, industrial production of the low-temperature circuit breaker began this year and a new research and development centre, CITEQ, was created.

TESTING OF ±500-KV CABLE PROTOTYPES FOR THE UNDER-RIVER CROSSING

Testing continued throughout the year on the ±500-kV DC cable prototypes for the under-river crossing of the transmission line linking James Bay with New England. The prototypes have been supplied by three cable manufacturers: Hitachi (Japan), Pirelli (Italy) and STK (Norway).

Although the Service Câbles et Isolants has assumed overall responsibility for this test program, the research work calls for specialists in various fields: overhead transmission lines, measurement, data processing, and high-voltage and high-power testing. Undertaken at the request of the Vice-présidence Équipements de transport, the project comprises two parts: conformance tests, which take place in the high-voltage laboratory, and aging tests in ductbanks at the new outdoor cable testing area. (See article on page 61).

Tests were conducted throughout the year at the high-voltage laboratory on the ±500-kV DC underground cable prototypes for the under-river crossing of the line from James Bay to New England.

The main purpose of the tests under way in the high-voltage laboratory was to check that the cables and accessories supplied by different manufacturers comply with Hydro-Québec specifications. The test protocol comprises a series of tests in conformity with CIGRÉ recommendations for DC cables and pollution tests. In addition, special tests have been devised to validate the cable design by subjecting them to disturbances characteristic of the St. Lawrence River crossing: lightning impulses followed by 10-kHz oscillations, and 60-Hz and 120-Hz alternating currents superposed on the direct current. Some of these tests have never before been applied to a cable of this class. The pollution tests are intended to check the behavior of the cable ends in driving rain and clean fog, with uniform and nonuniform contamination of the porcelains.

The Hitachi prototype underwent all the type tests, special tests and pollution tests during the year. Testing began on the other two prototypes and should be completed early in 1990.

The second part of the program, namely the outdoor tests, will take eleven months. The tests began in the fall with nine months of accelerated aging equivalent to approximately 30 years of service life; these aging tests comprise temperature and voltage cycling and polarity reversal. The program will continue by repeating most of the type tests and special tests performed at the beginning of the high-voltage laboratory project in order to verify the characteristics of the aged cables. Upon completion of these tests, the cables will be subjected to lightning impulses up to breakdown.

Each ±500-kV cable prototype, some 130 m long, was installed in one of the reinforced-concrete ducts available at the outdoor facility. A number of thermocouples were then placed at carefully selected points inside the conductor and on the surface, and the duct was filled with lean-mix concrete. The installation is designed to simulate as closely as possible the thermal and mechanical environment of the tunnel for which the cable is intended.

Tests were also conducted at the high-power laboratory to assess the mechanical resistance of the ducts and their fire hazards. The results were subsequently used to design a mechanically suitable duct which not only completely immobilizes the cable but ensures a safe environment for maintenance workers.

In other activities related to high-voltage cables, IREQ specialists helped evaluate cable manufacturers' bids prior to their testing of 800-kV AC cable prototypes to be used on future under-river crossings planned by Hydro-Québec. Three technologies are under consideration: cables with cellulose or synthetic paper insulation, and SF_6 rigid busbars.

Câbles et Isolants
(Cables and Insulation)
Laboratoire Haute tension
(High-Voltage Laboratory)

NEW VERSION OF THE HARMONIC-ANALYSIS PROGRAM

A new version of the harmonic-analysis program was developed in 1989. This version, A, is an intermediate step in a major development project for Hydro-Québec's power system planners.

The harmonic-analysis program is designed to calculate harmonic impedances of an electric power system from a frequency scan of the mathematical representation of the system in its steady state. It can also be used for load-flow analysis and analysis of the voltage sensitivity to harmonic-source injection frequencies. Calculation of electromagnetic interference and distortion factors is also available.

Version A is the result of a planned, complete restructuring of the harmonic-analysis program. All the single-phase and multi-phase network models are now compatible with the EMTP (ElectroMagnetic Transients Program) steady-state representation. Processing of the models has been standardized so that the available calculation options can be applied to all models, without distinction. Many can now be configured directly by the user. A data compiler flags the user's errors, replaces missing parameters with default values and validates the topology of the network to be simulated. The overall structure of the program is uniform and easy to use.

Méthodes numériques
(Numerical Methods)

EXPERT SYSTEM FOR EQUIPMENT DIAGNOSIS (SEDA)

The main objective of the SEDA project is to develop a family of expert systems for maintenance and troubleshooting operations on the electrical equipment of an entire substation. SEDA's general architecture and concept can be adapted to all types of equipment, which means that each expert system in the family can be developed step by step: SEDA-PX for equipment X; SEDA-G, an interface providing access to the local and corporate databases; and the man-machine interfaces needed by maintenance staff.

August 1989 saw completion of the SEDA-TRANSFO prototype, an expert system for power transformers. The prototype includes an analysis module which issues a diagnostic report on the equipment condition and a recommendation regarding its operation. This general report is based on the diagnostics produced by other modules of the system (dissolved-gas analysis, visual inspection, etc.).

This modular design of SEDA-TRANSFO allows the different components (apart from the analysis module, of course) to be used separately. The dissolved-gas analysis module, for instance, which combines NEXPERT and an interface adapted to the dissolved-gas analysis results supplied by the laboratory, is now available as an independent system.

Designing the interface with the corporate database posed a sizable challenge. SEDA-G, whose function is to select and update the data needed for processing the different SEDA-PXs, offers a possible solution to the data integration and filtering problem. Various tests have been successfully performed to verify the feasibility of the front-end concept. Meanwhile, FOXBASE+ is used to generate local databases for historical data on equipment.

Several other systems using the SEDA concept are under development: SEDA-CAT (for turbine cavitation analysis), SEDA-HUILE (for diagnosis based on analysis of insulating oils) and SUPER-DIAGNOSTIC (for diagnosis of generators).

The final version of the SEDA-TRANSFO prototype adapted to the needs of regional operators should be completed by the end of 1990.

Électronique
(Electronics)

EXSEMPLE PROJECT – COMPUTER-ASSISTED DESIGN OF SUBSTATIONS

A project is under way to demonstrate the feasibility of integrating expert systems into a computer-assisted design (CAD) context. Coupled with an expert system, CAD software such as Autocad can be used for actual design purposes, not just for drawing.

In this EXSEMPLE project, an expert system has been developed to help specialists in designing all types of substation, particularly distribution substations, and to verify the design in the process.

The new integrated tool allows the designer to use Autocad software to design a substation which is regularly verified by the expert system. Design is thus quicker and completely error-free.

The expert system was designed in collaboration with the Vice-présidence Équipements de transport, the client department, and took eight months of research and development to complete. The original objectives have been fulfilled and the system is now awaiting evaluation.

Électronique
(Electronics)

DC SIMULATION ON HYDRO-QUÉBEC'S AC NETWORK

During geomagnetic storms or when HVDC substations are operated in monopolar mode with ground return, DC voltages are created between AC substation ground grids. This allows DC currents to infiltrate the network via the transformer grounded neutrals.

It takes a relatively long time (60 s) for a transformer to saturate in one polarity and to start to generate harmonics which disturb not only the network itself but the operation of static compensators and other equipment. In fact, it is the failure of static compensators that led to Hydro-Québec's system-wide power failure on March 13, 1989.

Undertaken at the request of the Vice-présidence, Planification du réseau, IREQ's investigation began with an EMTP study of the phenomena involved, but the inherently long CPU times of this program led the research team to seek an alternative approach. It developed a simulation method which forces the transformer to reach steady-state operation in just a few seconds rather than in hundreds of seconds. The CPU time for EMTP simulations is thus reduced by a factor of almost 100, which significantly enhances studies of the impact of geomagnetic storms and grounding electrodes on the Hydro-Québec power system.

Appareillage électrique
(Electrical Apparatus)

PRODUCTION OF A NEW SF_6 CIRCUIT BREAKER

This year, joint research and development by Hydro-Québec and GEC ALSTHOM Énergie since 1985 led to the commercial production of the first models of a new SF_6 circuit breaker for low-temperature applications (-50°C). The decision to commercialize was based on the successful development of a laboratory prototype.

Known as the GFX circuit breaker, this device has the exclusive feature of being able to operate with pure SF_6 or an SF_6 gas/N_2 mixture, depending on the voltage level, without requiring any change in design.

To demonstrate their operating reliability, two breakers were installed in the field to switch shunt reactors, one rated 315 kV at Manic, the other rated 765 kV at Micoua substation. Additional acceptance tests will be performed in 1990 to examine all possible applications of the GFX and the full range of rated voltages from 72.5 kV to 765 kV.

Appareillage électrique
(Electricol Apparatus)

EVALUATION OF RELAYS AND AUTOMATIC CONTROLS (SERA)

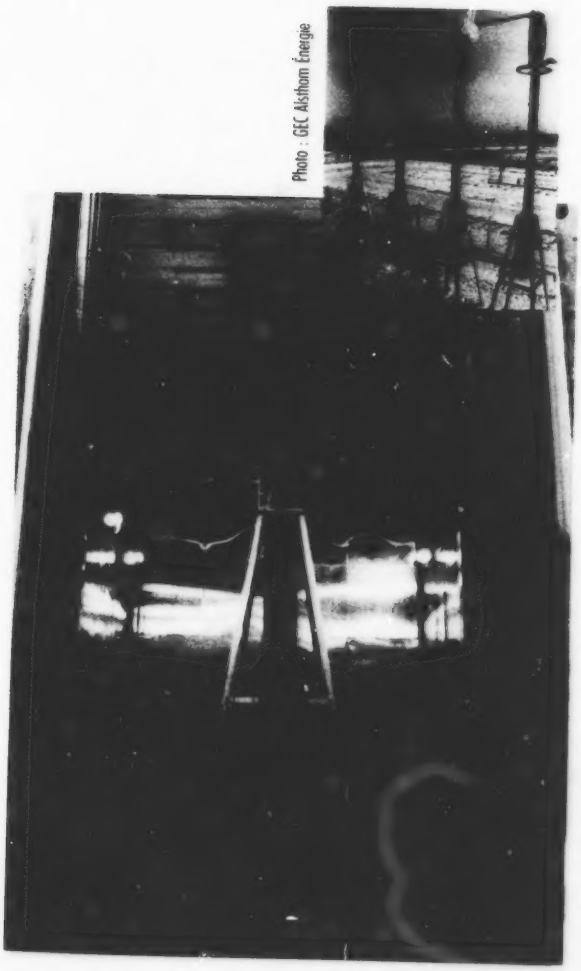
A new system for evaluating relays and automatic controls, known as SERA, was developed in 1989. It combines the multipurpose function of a computer-based test device with the simplicity of a conventional test bench. Demonstration of the prototype is scheduled for March 1990.

The hardware comprises a type 386 personal computer, a dedicated signal acquisition and generation unit, and voltage and current amplifiers. The personal computer is used to process test waveforms and results (database, display, statistics), to provide the man-machine interface and to control the peripherals. The latter record and reproduce signals coming in from substations and generating stations (voltage and current transformers for analogue data and electromechanical relays for logic states).

The test waveforms can come from a digital simulation on another computer (for example, an EMTP simulation), an analogue acquisition (on the analogue simulator or the power system itself) or a sequence keyed in directly by the operator.

To ensure the validity of the tests, the system comprises many built-in self-check and self-calibration functions, which makes its use very straightforward. Two versions are planned, a laboratory unit and a smaller, portable unit for field applications. The former can process up to 12 input and output analogue channels (six for voltages and six for currents), 64 logical inputs and 12 logical outputs. The field unit can handle up to six analogue channels, 16 logical inputs and three logical outputs

Photo : GEC Alsthom Énergie



One full 765-kV pole of the GFX circuit breaker at the GEC Alsthom Énergie plant. Industrial production of the new breaker began this year.

Mechanical and environmental tests were performed at -50°C on the interrupting chamber of the GFX circuit breaker to check for leaks.

SERA was developed at the request of Hydro-Québec specialists in fields ranging from automatic controls, protection, power system studies and system control to testing and technical appraisals, and power system management.

Méthodes numériques
(Numerical Methods)

MEASUREMENT OF CABLE SLEEVE MISALIGNMENT

Following a study for Hydro-Québec's transmission line hardware specialists, two new methods for measuring cable sleeve misalignment were developed. The aim of this joint study with Tecrad was to determine, by means of nondestructive methods, the degree to which aluminum sleeves are off centre in relation to the steel core of the overhead cable on which they are installed.

The first method is based on magnetic induction. A magnetic field is induced by a strong permanent magnet and the position of the steel core is measured with a Hall effect probe and an encoder. This provides a characteristic curve of the position of the steel sleeve inside the joint. Although the magnetic field variation is very slight, it can nevertheless be detected sufficiently accurately for measuring misalignment to the nearest 5 mm. The system developed can easily be automated and lends itself to field applications.

The second method is based on the principle of electrical resistance. In this case, it is the variation in resistance which allows the position of the inner steel sleeve to be measured. For this purpose, the researchers built a jig to which they attached a series of electrodes. The sensitivity of the microhmmeter yields highly accurate data: the maximum deviation recorded for marked misalignment was about 0.5 microhms.

The second method is of particular interest in that it allows various characteristics to be measured, including the overall resistance of a joint. It could therefore be used for assessing the general quality of both new and in-service joints. In collaboration with the Direction Appareillage, the new jig has now been adapted so that it can be used to check soldered joints during power generator rewinding operations. Tests are now under way at Bersimis 2.

Chimie des matériaux
(Materials Chemistry)

ASSEMBLY WELDING OF ELECTRICAL CONDUCTORS

A study was recently initiated at the request of several Hydro-Québec departments to assess the quality of welded conductor assemblies. Several expert appraisals have already been conducted on brazed joints of low-voltage connections on power transformers at La Grande 2 and 4 as well as on grounding connections. The evaluation method combines conductivity measurements, metallographic examinations, heat-cycling and melting tests.

The main objective of this project is to develop new assembly welding techniques in order to improve joint quality, streamline the manufacturing process and, ultimately, increase equipment reliability. To meet this goal, the research team plans to apply resistance brazing and welding and MIG arc welding.

Technologie des matériaux
(Materials Technology)

PHASE-ANGLE MEASURING SYSTEM

The phase-angle measuring system for the Vice-présidence Production, Transport et Distribution was completed this year. Now in its third version, the system is used primarily to obtain a province-wide view of Hydro-Québec's 735-kV transmission network. Thus, when an incident occurs, its exact location can be determined, its nature identified (short circuit, tripped line, generation loss, load loss, etc.) and its severity assessed immediately.

The system is fed with data from four permanent measuring stations (Boucherville, Châteauguay, Arnaud and La Grande 2) which send the peak voltage and the voltage zero-crossing time every cycle to a central acquisition unit. There the measurements are analysed and all disturbances exceeding predetermined limits are recorded, in real time.

Personal computers or graphic terminals provide users with access to this data from which they can derive the voltage, frequency, phase-angle deviation and other values needed for their calculations. The data can also be sent directly to the user's computer in digital form.

Activities in 1989 included putting into service the data processing software for users, and producing documentation on the hardware and software of the measuring system. In addition, software was designed for real-time transmission of some of the data to the computers at the System Control Centre to make it accessible to power system operators. The operators can thus swiftly detect voltage asymmetry, the sign that a magnetic storm capable of affecting the power system is about to begin. Operators can therefore take the necessary steps to prevent effects such as those in March 1989, which resulted in a province-wide power failure.

Électronique
(Electronics)

FIBRE OPTICS ACTIVITIES

The various activities undertaken in 1989 in the field of fibre optics centered principally on telecommunications and current transducers.

With regard to telecommunications, IREQ's mechanical-engineering and electronics specialists conducted a pilot study of a new type of overhead ground wire comprising a fibre-optic bundle. The aim of this experiment, which is under way at the Îles-de-la-Madeleine test site, is to assess the long-term mechanical behavior of the ground wire and the data transmission quality. The work is being done in cooperation with the personnel of the Maisonneuve and Matapédia regions and the Hydro-Québec departments requesting the study.

From the mechanical point of view, the focus is on determining the effect of the vibrations to which the cable is exposed. This data will provide a basis for evaluating the lifetime of the wire and for developing installation and testing procedures, especially for fatigue resistance tests in the laboratory.

As far as the optical aspects are concerned, the aim is to measure the effect of the mechanical stress of the overhead ground wire on the transmission quality. To this end, various parameters are recorded every 15 min: wind velocity, temperature, vibration amplitude and frequency, etc. Signals are transmitted over the optical fibres and their characteristics – the attenuation rate, mainly – are measured at the same time. Correlation is then established between mechanical stress and transmission quality.

The overhead ground wire being tested on the experimental line at Îles-de-la-Madeleine comprises eight optical fibres in an aluminum tube around which nine aluminum-coated steel strands are wound. Installation was completed in September and was followed by the first stage of the tests, which took two months. The second stage, also scheduled to last two months, will be conducted next spring.

The greatest advantage of optical fibres for telecommunications is that they are naturally immune to electromagnetic interference. In addition, when used on new power lines, fibre optics offers a more cost-effective technique than the traditional microwave technology.

Overhead ground wires incorporating fibre optics were studied in 1990.

With respect to fibre-optic transducers, a project was undertaken for the Canadian Electrical Association on high-voltage optical fibres used with current transducers installed on transmission lines, among other applications. The final report on this study describes various tests aimed at determining the changes that take place in the fibres themselves and in various systems using energized optical fibres.

Lastly, a laboratory prototype of a laser Doppler velocimeter has been built for measuring the instantaneous rotation speed of electrical machines. One application envisaged for this device is in the stabilizers of these machines.

Électronique
(Electronics)
Mécanique
(Mechanical Engineering)

QUADRATURE ASYNCHRONOUS DEVICE

Hydro-Québec keeps a watchful eye on new technologies that lend themselves to interconnections either within its own power system or with other systems for export purposes. One such technology is the multi-purpose quadrature asynchronous device, which can function simultaneously as a DC interconnection and as two static compensators.

IREQ's analyses show that the quadrature asynchronous device is a very effective interconnection technology. Its great flexibility allows the export capacity to be increased without recourse to rotating machines.

Many other applications are envisaged: power dispatching, increasing the line transfer capacity, islanding, and asynchronous operation of generating stations, among others.

This study was conducted with Hydro-Québec's testing and technical appraisals experts for the Groupe Équipement.

Appareillage électrique
(Electrical Apparatus)

EFFECTS OF FOREST FIRES ON TRANSMISSION LINES

Work continued in 1989 on research into the effects of forest fires on high-voltage transmission lines. Fires are known to cause faults which result in service interruption. The aim of the research project is to determine the critical operating conditions for AC and DC lines exposed to fire.

The first stage of the work was to analyse the test data collected over the last two years. It was evident that flames have a significant influence on air insulation, as confirmed by an analysis of recent statistics. Then followed an inspection of several lines which had been exposed to forest fires. Work began, too, on a new high-speed acquisition system for analysing transient phenomena.

The results so far show that system reliability would benefit from new right-of-way clearance and maintenance standards.

Lignes aériennes
(Overhead Lines)

LIGHTNING-CURRENT MEASURING SYSTEM FOR TRANSMISSION LINES

A team of scientists and technicians has developed a battery-operated lightning-current recording and measuring system for HV transmission lines. Earlier research had shown that it was essential to know the full lightning-current waveshape in order to understand the phenomena that cause major faults on transmission lines.

Two of the basic components of the system, the current transducer and the data acquisition unit were developed from scratch but the third, a solar-battery charger to provide an independent power supply, is a commercial device.

The current transducer is based on torroidal-current coil technology, which means that the device can be built large enough to be clamped round the overhead ground wire support.

The acquisition unit was designed and built by CPU Design. The recorder has a sampling rate of 10 MHz (10 million samples per second) and its power requirements are minimal.

The three components form an effective system which records the lightning-current waveshape in an electronic memory after indicating the exact time of the measurement. The stored data can be read by a portable computer using a standard fibre-optic communication link.

Some 20 such systems will be installed at strategic points throughout the network, especially at river crossings where the towers are very high, to record the lightning currents during the 1990 lightning season and the three that follow.

The data gathered will be used to validate line protection models with direct measurements and will also allow the research team to establish reliable values for the amplitude of lightning overvoltages, which are responsible for punctured insulators and accelerated aging of line hardware.

Lignes aériennes
(Overhead Lines)

Rain tests on a porcelain cylinder simulating an HVDC cable end.

UPGRADING THE PERFORMANCE OF HVDC WALL BUSHINGS AND CABLE ENDS

Various reliability problems have been detected in HVDC wall bushings in recent years and a research project was therefore initiated in 1989 to determine their cause. The investigation also covered HVDC cable ends.

The work comprised the following tasks:

- Rain tests were performed on a hollow porcelain cylinder to study the behavior of combined (AC and DC) sources at voltages up to 970 kV peak.
- Artificial-pollution tests were performed on a hollow porcelain cylinder simulating a cable end to measure the critical flashover voltage under various nonuniform contamination conditions. The purpose of these tests was to establish the worst conditions for the type tests to be conducted on HVDC cable ends.
- Type tests were conducted under rain and combined AC/DC voltage conditions together with DC voltage tests on one type of 450-kV cable end in the presence of nonuniform contamination and under fog conditions.
- A theoretical analysis was performed of voltage distribution in the model of a bushing with a capacitive screen.
- A mathematical model was formulated for simulating flashovers on wall bushings. The model takes account of the surface conditions and the internal construction of the bushings, with representation of their capacitive and resistive elements. The theoretical results agree with the experimental results obtained during nonuniform rain tests on a conventional 600-kV wall bushing.

Lignes aériennes
(Overhead Lines)
Laboratoire Haute tension
(High-Voltage Laboratory)

EFFECTS OF FREEZING RAIN AND SNOW ON TRANSMISSION LINE INSULATION

It is widely acknowledged that severe conditions of freezing rain or even snow alone can cause flashover on transmission line insulators. In accordance with the Technology Plan 1989-1991, a project was therefore initiated to determine the exact effect of these conditions on line insulation and transmission hardware.

It is planned to use a high-voltage environmental test chamber for the purposes of this project and contact was consequently made with ice experts at the Université du Québec à Chicoutimi to establish the design parameters for this new facility, which is scheduled to go into operation in 1991.

In the meantime, a review of the available literature was undertaken to gather data on flashover mechanisms as well as on ice testing facilities and procedures. A statistical study was also conducted to examine the cases of unavailability that have affected the Hydro-Québec transmission system and to trace the climatological patterns of freezing-rain storms in Québec. A systematic follow-up program is now being implemented to examine power system behavior under all winter weather conditions.

Lignes aériennes
(Overhead Lines)
Laboratoire Haute tension
(High-Voltage Laboratory)

BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS

All projects related to Hydro-Québec's action plan on the effects of electric and magnetic fields marked significant progress in 1989. Most of these projects were conducted for the Vice-présidence Environnement.

In the study on human perception of the electric fields and ion currents produced by direct-current lines, for example, final touches were put to the design and construction of an exposure chamber. The chamber will be used to simulate conditions that can occur under DC transmission lines. Environmental Research Information, the research team's New York consultant on the psychophysical aspect of this project, has developed a draft protocol for the studies to be conducted on human beings.

In addition, a device has been designed for measuring and recording the vertical electric field and the magnetic field on three orthogonal axes at a frequency of 60 Hz, over 24-hour periods. With three prototypes already built, work has begun on a project aimed at establishing the characteristics of electric and magnetic fields in different environments. Measurements had been taken in a dozen houses and apartments by the year-end.

With respect to the epidemiological study undertaken jointly by Hydro-Québec, Ontario Hydro and Électricité de France, the IREQ team contributed to the calibration and final adjustments of the dosimetry software.

Meanwhile, work was completed in spring 1989 on the measurement program related to Hydro-Québec's environmental follow-up on the ±450-kV DC link. An exhaustive analysis of the results is now under way.

As far as the study on electrical burns is concerned, impedance measurements have been taken on different organs of five animal species. The results show that each organ has its own "electrical signature", which is similar for the same organ, whatever the species.

Lastly, the team contributed to two of the information projects provided for in the action plan. The first involves the construction of an electric and magnetic field demonstration centre in the grounds of IREQ. (See article on page 62). The second is the publication of a document entitled "Electricity in the Air", which explains field effects in layman's terms for the general public.

Lignes aériennes
(Overhead Lines)

MECHANICAL BEHAVIOR OF SUBSTATION EQUIPMENT

A new research team within the mechanical engineering group was formed in 1989 to take on responsibility for all activities related to substation equipment.

One aspect of their research involves a study of adfreeze heaving of augered caisson footings.The study is aimed at optimizing the design of this new type of footing which, being more economical and faster to build, is to be used for lightweight equipment in future substations.

A first series of tests was performed at two sites, Beaupré and Lévis substations, both of which are located on highly frost-susceptible soil. An analysis of the test data yielded a preliminary comparative evaluation of the different types of caisson footings. Those with surface thermal insulation proved far superior. In a second series of tests planned for winter 1990, an original technology designed to minimize the effects of adfreeze heaving will be tested on new footings specially built at Beaupré substation.

The research team also studied the mechanical strength of power transformer tanks under arcing conditions. A new analytical model was developed for studying the structural behavior of tank walls using a parametric study of the main characteristics. In addition, a numerical method was successfully applied to the problem of transformer explosion; this is the first time such an application has been attempted. Lastly, a model test laboratory was set up for scale modeling of phenomena related to internal breakdown.

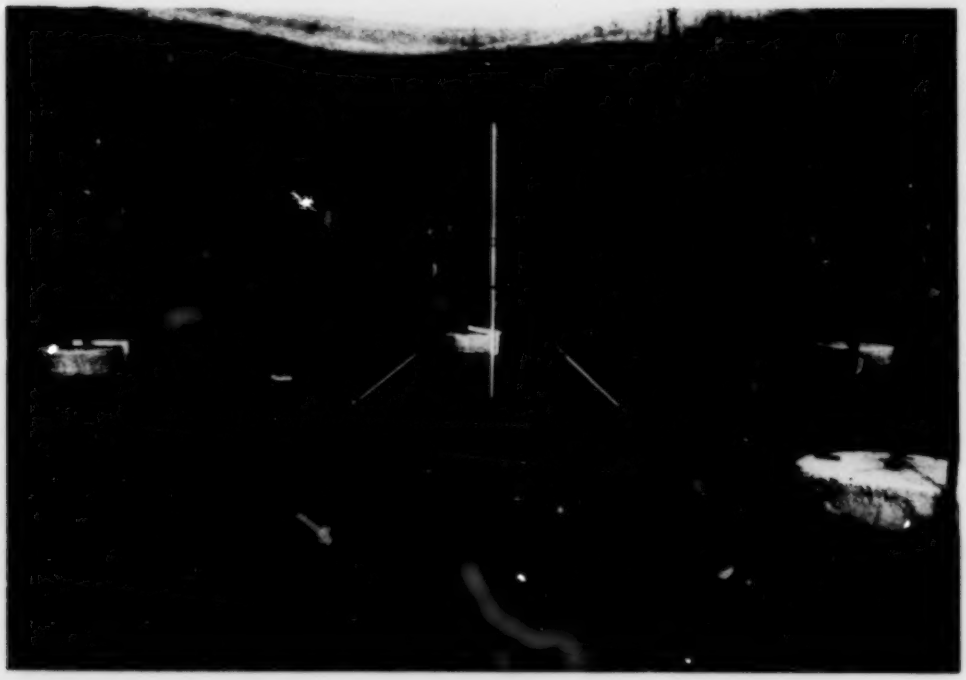
Mécanique
(Mechanical Engineering)

STUDY OF LOW-SAG BUNDLE CONDUCTORS

The last phase of a series of observations undertaken with a view to measuring the sensitivity of low-sag bundle conductors to wind-induced vibrations drew to a close this year. Initiated in 1987 for the Canadian Electrical Association and Hydro-Québec's transmission system equipment specialists, the study was carried out largely on the experimental line in the Îles-de-la-Madeleine.

The first analyses corroborated the assumption that bundle conductors equipped with spacer-dampers can be strung with much less sag than single conductors in any location where the ice load does not play a determining role. By reducing the sag, the tower height can also be reduced, leading to considerable savings in line construction costs.

Mécanique
(Mechanical Engineering)



Test station for studying the adfreeze heaving of augered caisson footings at Beaupré substation near Québec City.

CONDUCTOR SELF-DAMPING CALCULATION MODEL

In 1989, final touches were put to a semi-empirical model for calculating the self-damping of ACSR (aluminum conductor steel-reinforced) and ACAR (aluminum conductor alloy-reinforced) conductors. Marked progress was thus made in the calculation of overhead-conductor response to eolian vibrations. Hitherto, each conductor of the same type had to be tested in the laboratory to determine its self-damping characteristics, an operation which was as tedious as it was costly. Now the required parameters can be readily derived from the model for the conductors of the corresponding class. The new model has already been incorporated into IREQ's various overhead conductor vibration calculation programs.

This work was undertaken for the Vice-présidence Équipements de transport.

Mécanique
(Mechanical Engineering)

MODELING OF CONDUCTOR-SPACER-DAMPER SYSTEMS

Work has terminated on the modeling studies related to conductor-spacer-damper systems under eolian-vibration conditions. The outcome is a model capable of processing all asymmetries, whether they affect the characteristics of the conductors and anti-vibration devices or the subconductor settings. In addition, the model matches the eolian vibrations with random magnitudes and also takes account of the influence of natural wind turbulence on conductor excitation; this results in a far more accurate reproduction of the phenomena involved.

From this model a new computer program known as VIBÉOL was derived. Its first application was for the temporary overhead St. Lawrence River crossing between Grondines and Lotbinière in the context of the James Bay – New England project.

The development work was sponsored by the Vice-présidence Équipements de transport.

Mécanique
(Mechanical Engineering)

IMPLEMENTATION OF SERIES COMPENSATION

Several studies were conducted on series compensation in 1989. The first, requested by Hydro-Québec's power system planning experts, was a simulator study aimed at establishing the maximum overvoltages and energy constraints to which series compensation equipment, especially arresters protecting capacitors, will be exposed. The results of this study made it possible for the equipment division to optimize the system parameters and hardware characteristics and to finalize the technical specifications ready for tendering.

Simulator study of new protection systems required for series-compensated lines.

The last 12 months also saw the initiation of an exhaustive study of the performance of the protection systems on series-compensated lines. This study, for the Vice-présidence Équipements de transport, is the largest simulation study of its kind ever undertaken. It involves the simultaneous study of no less than ten protection systems from five different manufacturers on a simulation of Hydro-Québec's entire power transmission network.

The protection relays presently used on the network are impedance relays, which were not designed to be installed on series-compensated lines. The objective of this study is thus to evaluate new types of relay that are specifically designed to be compatible with series-compensated lines.

The relays currently being studied are of both static and microprocessor types. They are based on various operating principles: impedance measurement, overcurrent, traveling wave, current differential and phase comparison. Some of these relays are so new that they are at the first stage of their acceptance tests.

The test program is carried out in cooperation with the testing and technical appraisals team from the Maisonneuve Region. Four power experts from the equipment division are working at the simulation centre to analyse on site the study results produced by the simulator and the study team.

Études de réseaux
(Power System Studies)

STUDY OF THE CHÂTEAUGUAY INTERCONNECTION

A study of the performance and control optimization of the Châteauguay DC interconnection was successfully completed in 1989. The study demonstrated the feasibility of operating the link in the import mode and with second-harmonic filters; in addition the study team was able to optimize the HVDC control system settings for the various modes of operation.

The proposed modifications were successfully implemented at the substation, whereupon the utility was able to significantly increase the authorized level of its electricity exports to the New York Power Authority, and to import from NYPA during periods of peak consumption in Québec.

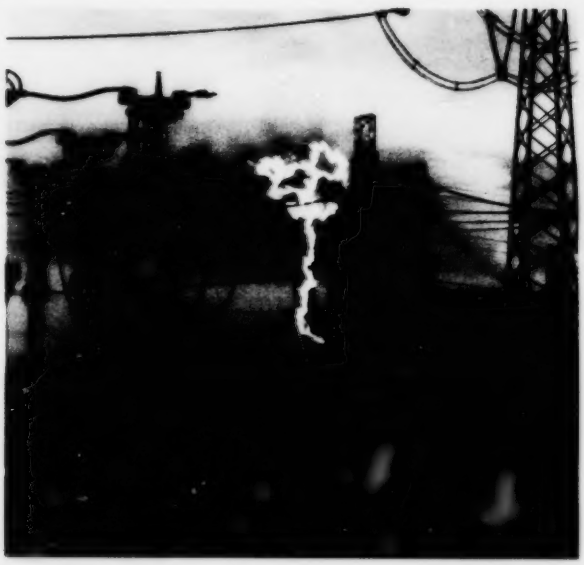
The study was conducted in collaboration with Hydro-Québec transmission and interconnection specialists and personnel from the Maisonneuve Region.

Études de réseaux
(Power System Studies)

ELECTRICAL TESTS AT THE HIGH-POWER LABORATORY

In an attempt to determine their effects on the transmission of light signals, short-circuit-current tests and power-arc tests were performed on overhead ground wires containing optical fibres.

The first test consisted in passing a short-circuit current of approximately 20 kA for 30 cycles through the conducting metallic jacket of the ground wire. The wire had been preheated to 50°C and strung at 10% of its ultimate tensile strength with the result that the current produced thermal and mechanical stresses on the outer optical fibres, stresses great enough to affect the transmission of light at wavelengths of 1300 and 1550 nm. The length of the overhead ground wire was 10 m while that of the optical fibres was at least 100 m (ten butt-spliced fibres). The test was completed by applying a mechanical stress equal to 75% of the ground wire's ultimate tensile strength.



Tests at the high-power laboratory on the extinction of secondary arcs and single-phase reclosing of 315-kV lines.

In the power-arc tests, a fuse wire was used to trigger a power arc of approximately 20 kA, 6 cycles, between the overhead ground wire and a parallel conductor. The aim of these tests was to determine the influence of the arc on fibre-optic transmission.

Other tests were performed on the interruption chamber of one pole of an SF_6 high-voltage circuit breaker. A back-to-back capacitor bank was used for these current-making and breaking tests. A capacitive inrush current, 20 kA peak, 4250 Hz, was generated when the breaker closed as a result of a capacitor bank on the source side of the breaker discharging into a capacitor bank on the other side: once the inrush current has been damped, the breaker has to interrupt a 630-A capacitive current at a voltage of 115 kV.

Lastly, tests were conducted on a current-limiting reactor. The air-core dry-type, 2-mH, 230-kV reactor equipped with an anti-seismic damper was subjected to short-circuit withstand tests at 26.7 kA rms, 60 Hz, for 3 s, with a first asymmetrical peak at 75.6 kA.

Laboratoire Grande puissance
(High-Power Laboratory)

MECHANICAL TESTS AT THE HIGH-POWER LABORATORY

New string insulators were subjected to thermomechanical endurance tests followed by electromechanical tests. The thermomechanical test comprises four heating and cooling cycles at extreme temperatures, with an applied mechanical tension equal to 70% of the rated value. Each 24-h cycle consists in lowering the insulator temperature to -50°C, keeping it there for 4 h, then raising it to +50°C and again keeping it at that level for 4 h.

In the electromechanical test, the insulators are subjected to an applied voltage at the same time as the mechanical strain is increased.

In addition, electromechanical breaking tests were performed on field-aged porcelain string insulators removed from old (60 years or more) Hydro-Québec transmission lines. The tests were designed to determine the condition of these devices, and the results allowed the research team to establish the mechanical rupture and dielectric-breakdown limits.

The interruption chamber of an SF_6 high-voltage circuit breaker was subjected to environmental tests at -50°C. The aim of these tests, which took place in the 8.3 m x 6.5 m x 4.8 m environmental test chamber, was to measure the SF_6 leakage rate to ensure the low-temperature circuit breaker was gastight. At -50°C, the leakage rate should be not more than six times the rate measured at +20°C. The gas escaping from the joints of the interrupting chamber and of the driving rod was collected in plastic bags and measured. Measurements were also made of several operating characteristics: closing speed and duration, opening speed and duration, gas pressure and ambient temperature in the control cabinet.

Laboratoire Grande puissance
(High-Power Laboratory)

TESTS ON RAPID-TRANSIT EQUIPMENT

Mechanical-fatigue qualification tests were performed on the welded connection of a cross piece with the side sill of an underground railway car. Two hydraulic jacks served to subject the sample three million times to a vertical force of 7606 N and a horizontal force of 333.6 N at a frequency of 10 Hz. The sample was inspected visually after every 500,000 cycles. This test program was undertaken for a rapid-transit equipment manufacturer.

In addition, short-circuit-current withstand tests were performed on a converter-transformer to be used to feed the rapid-transit system in a North American city. The equipment included one 34.5 kV/750 V, 3.2-MVA transformer, shielded busbars and a power diode bridge.

Laboratoire Grande puissance
(High-Power Laboratory)

TESTS AT THE HIGH-VOLTAGE LABORATORY

Over 200 contracts were obtained in 1989 involving tests on high-voltage apparatus both for Hydro-Québec and for various manufacturers. Over 45 power transformers, 120 current transformers and 25 voltage transformers passed through the laboratory during the year. Five ASEA Brown Boveri $315/210/210\sqrt{3}$ kV, 404-MVA transformers built at their plant in Varennes for the Radisson HVDC converter station were also tested.

Another ABB unit destined for Radisson, a 500-kV wall bushing, was subjected to an extensive program of tests in the pollution chamber to assess its behavior under extreme operating conditions. The program included tests under uniform and nonuniform rain, as well as clean-fog tests.

Clean-fog tests were also performed on the 500-kV DC support insulators for the same substation.

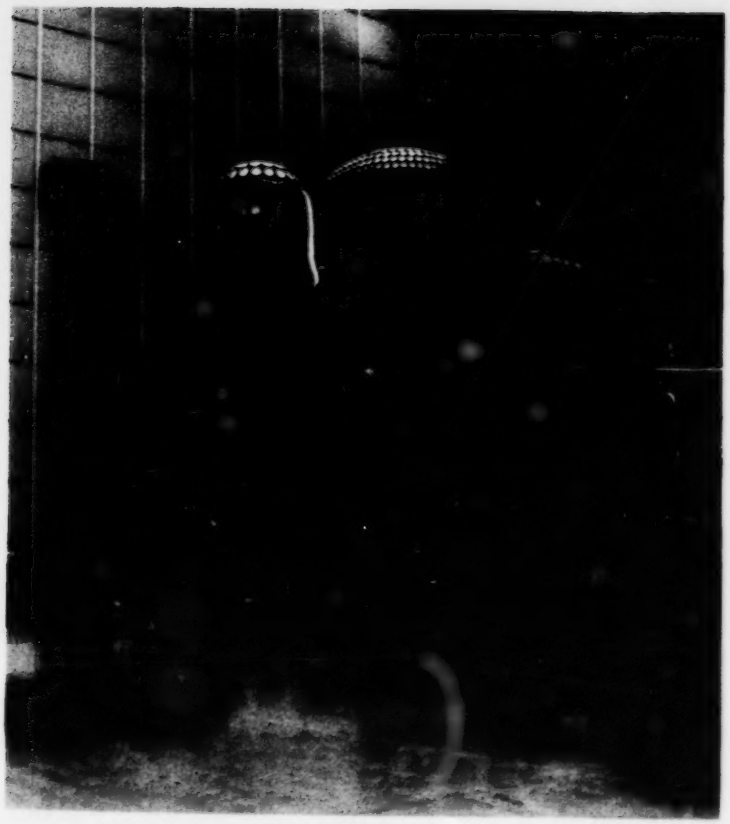
The team responsible for these activities also contributed to the tests on the ±500-kV cables for the crossing under the St. Lawrence River. (See article on page 20). Tests on the Hitachi prototype were completed in July, with testing of the Pirelli and Alcatel STK prototypes scheduled to begin early in 1990.

Laboratoire Haute tension
(High-Voltage Laboratory)

CREATION OF A TECHNOLOGICAL INNOVATION CENTRE

Hydro-Québec and ASEA Brown Boveri have formed an association to create a research and development centre for high-voltage power transmission systems and equipment. CITEQ (Centre d'innovation en transport d'énergie du Québec) will have a starting fund of $4 million and an operating budget of $10 million spread over five years. It will be located near IREQ in Varennes and will employ some 20 researchers from the two founding organizations.

CITEQ's first aim will be to improve the reliability and capacity of large electric systems and interconnections. To do so, it will call upon the scientific expertise of both TAI and ABB researchers. Among the initial studies to be pursued, mention might be made of the reliability of high-voltage power transformers and digital voltage and current measurement.



Tests on current transformers in the high-power laboratory.

DISTRIBUTION

A nonfragmenting surge arrester was developed in 1989 and research is under way on technologies that allow amorphous steel to be employed in the construction of magnetic circuits for distribution transformers.

Various studies were conducted on the quality of customer service and on different means to enhance safety in underground systems exposed to fault arcs. Meanwhile, work continued on an analysis of transformer vault corrosion together with the remedial measures, and on a study of copper-aluminum connectors in a saline environment. An investigation has begun on the environmental diffusion mechanisms of pentachlorophenol, a preservative used for wood poles.

With regard to extruded cables, progress was made in the studies of dielectric breakdown, oxidation and water treeing, and a cable-aging model was developed.

DEVELOPMENT OF A NEW DISTRIBUTION SURGE ARRESTER

Hydro-Québec has a new standard on zinc oxide nonfragmenting surge arresters for its distribution system. To meet the requirements of this standard, an arrester with a polymer-concrete housing has just been developed jointly with Joslyn Canada.

The new standard raises the arrester rated voltage from 18 kV to 21 kV and tightens the safety requirements: in the event of an internal fault, the arrester must not shatter or burn, even under extreme contingencies. This is now the most stringent standard in the world as far as safety is concerned.

In spring 1989, the new arrester underwent a series of short- circuit tests at IREQ's high-power laboratory. (See article on page 40). These tests (8 kA, 0.2 s) were performed with a source producing a strongly asymmetrical current with a 2.7 p.u. peak. A new test procedure consisting in gradually producing a fault in the arrester due to thermal runaway was used for this series of tests. Moreover, these tests were far more exacting than the previous series. A dozen other types of test were successfully performed at the high-voltage and high-power laboratories including: artificial-pollution, mechanical, watertightness, dielectric-strength and current-wave injection tests, to name but a few.

The original design of the polymer concrete surge arrester has now been modified to optimize its operation and reduce the manufacturing costs. For example, the arrester support has been changed and the inserts holding the nozzle used to expel fault-induced internal arcs have been relocated. The profile of the arrester has also been altered to lengthen the leakage path. The housing is made in Québec by Zagram Canada Ltd.

Some 500 units have now been manufactured and will be installed on the Hydro-Québec system for certification tests. Meanwhile, in view of the arrester's safety feature and the competitive price achieved by a simplified and fully automated manufacturing technique, it is planned to adapt the device for European power systems.

Appareillage électrique
(Electrical Apparatus)

CUSTOMER-SIDE MEASUREMENT OF THE POWER QUALITY FACTOR

In the last five years, Hydro-Québec has spent one billion dollars on upgrading service quality throughout its system. The effort has been devoted largely to service continuity but has not neglected the quality-factor aspect.

The aim of the first stage of this project was to measure the customer's present quality factor, taking account of the following phenomena: flicker, voltage unbalance, harmonics, overvoltages, voltage sags and momentary interruptions.

1989 saw the completion of an in-depth analysis of voltage unbalance measurements. The first results reveal constant fluctuation in the voltage unbalance. Interpretation of the measured data is complicated, because the point where unbalance begins to hamper operation of the customer's equipment is difficult to identify. A mathematical method was therefore developed for taking into account the inherent operating constraints of this equipment, and the method is now being used as the basis for the design of a voltage-asymmetry analyser, which will be available by 1992.

Lastly, to ensure consistency in processing the different types of distortion, a related project was initiated to develop a measurement protocol for accurately assessing the power quality factor. This work is being performed for the vice-présidence Production, Transport et Distribution and the Canadian Electrical Association.

Appareillage électrique
(Electrical Apparatus)

IREQ researchers have developed a new non-fragmenting distribution surge arrester in collaboration with Joslyn.

DEVELOPMENT OF A POWER QUALITY MONITOR

One of the projects related to power quality assessment involves the development of a new monitoring device. It is to be used as a diagnostic tool for the evaluation and interpretation of disturbance phenomena in the power distribution network.

This project is a result of an earlier assessment of the existing devices for analysing such phenomena. Many were evaluated based on their technical specifications and two were tested in the laboratory. None were found to completely satisfy Hydro-Québec's requirements.

The first phase of the project will consist of hardware development and the implementation of phenomena related to low-frequency disturbances:

- periodic variations (1-25 Hz) in rms voltage, known as flicker
- nonperiodic sharp changes in the rms voltage (surge/swell)
- active and reactive power.

The following phenomena related to high-frequency disturbances will be implemented in the second phase of the project:

- calculation of harmonics (up to 50th) on voltages, current and power
- waveform impulse detection.

The system consists of a portable computer, with an eight-channel analogue-to-digital converter, and an isolation and conditioning interface. The system acquires pertinent data automatically for a preset period of time. It then extracts the disturbance characteristics from the data and later stores them for display or for further processing.

The development of the system will start in January 1990 and the first tests are due the following December. The project has been undertaken at the request of the Vice-présidence Production, Transport et Distribution.

Méthodes numériques
(Numerical Methods)

EFFECTS OF FAULT ARCS ON UNDERGROUND DISTRIBUTION SYSTEMS

Fault arcs on underground equipment, albeit rare, can have serious consequences. A study was therefore initiated this year with a view to increasing the safety not only of operating and maintenance personnel but of the public at large.

The research team began by establishing that a fault arc lasting eight cycles on a 16-kA, 25-kV cable generates a large amount of energy mainly in the form of heat, but also radiation, material-decomposition energy and noise, all of which must be dissipated in the environment. For example, the temperature of the air in an average manhole can rise to 50°C while the pressure can reach 0.2 atm, which is enough to lift off the cover.

The aim of the next stage in this project for the Canadian Electrical Association is to find the means to reduce the risks of fault arcs occurring in distribution systems.

Appareillage électrique
(Electrical Apparatus)

AMORPHOUS-STEEL MAGNETIC CIRCUIT FOR A 100-KVA TRANSFORMER

Work is currently in progress on a technique for manufacturing amorphous-steel magnetic circuits under a licensing and R&D agreement between Hydro-Québec and Ferranti-Packard Transformers. The development is based on a Hydro-Québec patented design.

Amorphous ferromagnetic steels are known for their low hysteresis and eddy current losses. Their use in building magnetic circuits for distribution transformers could result in significant energy savings.

For the time being, however, the brittleness of amorphous steels and their extreme sensitivity to mechanical stress severely curtail their industrial application potential. Mechanical stress increases both hysteresis and eddy current losses. The problem can be circumvented with the aid of a suitable design and a special coiling technique for building the magnetic circuit, both of which have been developed and tested on a preprototype distribution transformer built at IREQ.

The objective of the joint Hydro-Québec-Ferranti-Packard project is to produce a dozen prototype 100-kVA distribution transformers with the new amorphous-steel magnetic circuits. Development and use of this new type of transformer will provide an opportunity to assess its economic viability.

Technologie des matériaux
(Materials Technology)

BREAKDOWN MECHANISMS OF DISTRIBUTION CABLES

Hydro-Québec and the Canadian Electrical Association have launched a joint research project with electrical engineers at the National Research Council Canada to study the dielectric breakdown mechanisms of polyethylene insulation in the presence of water treeing. It is known that this phenomenon often appears in the insulation of underground cables with polyethylene jackets but no moisture barrier. The effect is a reduction in the cable's dielectric strength, which leads to premature breakdown and decreases equipment reliability.

Accelerated growth of water trees in polyethylene samples will allow the residual dielectric strength to be measured as a function of the length of the water trees. It will also be possible to establish the characteristics of an electric tree initiated by a water tree by determining the increase in the amount of light emitted from the end of this water tree.

The project comprises two other parts: a study of the birefringence induced by electric stress, and, in order to study the DC space-charge accumulation, measurement of the electroluminescence of polyethylene under voltage impulses.

Câbles et Isolants
(Cables and Insulation)

MODIFICATIONS TO XLPE CABLE SPECIFICATIONS

A number of modifications to Hydro-Québec's technical specifications for XLPE (cross-linked-polyethylene) insulated medium-voltage cables were proposed in 1989. These recommendations are based on knowledge acquired during a characterization project involving aged extruded cables for the Richelieu Region and on experience built up over the last 15 years.

The following recommendations were formulated and submitted to Hydro-Québec's distribution specialists:

- to comply with Standard AEIC-CS5, with a few addenda;
- to use better-quality raw materials;
- to improve the manufacturing process;
- to implement Hydro-Québec's quality-control measures at the manufacturer's plant.

Other recommendations aimed at tightening the requirements of the standard, thereby improving service quality, include long-term laboratory and field tests on new cable technologies.

Câbles et Isolants
(Cables and Insulation)

Electrical-aging model for extruded cables

An electrical-aging model for extruded cables has been developed under a project financed by the Electric Power Research Institute (EPRI) in an aim to design a model capable of reproducing the results of accelerating-aging tests and to predict the real service lifetime of the cables. Theories abound on cable aging but none allows predictions about normal cable operation.

The proposed model is based on data on cables with polyethylene (cross-linked or not) and ethylene propylene rubber (EPR) insulation and, also, on various well-known theories and recent laboratory experiments. The equations allowing the cable service life to be predicted under different electric-field, temperature and environmental conditions proved relatively simple and sufficiently reliable to produce very satisfactory approximations. A few aspects remain to be examined before the set of predictions derived from the theory can be confirmed, but the model can already be used to assess the service life of new cables. The final report on this project will be published by EPRI in 1990.

Câbles et Isolants
(Cables and Insulation)

Oxidation in water trees

Little is known about the origin and the growth mechanism of defects in polymer-insulated cables, although several theories have been put forward. One such theory is that oxidation of the polyethylene in the insulation accelerates the formation and growth of water trees, as these defects with their branch-line appearance are known. A joint fundamental research project was therefore undertaken with the Electrical Engineering Department of the National Research Council Canada to examine this hypothesis.

Financed by the Electric Power Research Institute (EPRI), the study had as its objective to prove beyond all doubt whether oxidation could be traced in water trees found in service-aged cables. Analysis of the results revealed that the presence and level of oxidation cannot be linked in any way to the concentration or growth of trees in cable insulation. To support this conclusion, water trees were grown in pre-oxidized polyethylene samples in the laboratory. The oxidation level had no significant impact on tree growth, which demonstrates that water treeing is totally unrelated to the thermal-aging phenomenon in extruded cables.

Câbles et Isolants
(Cables and Insulation)

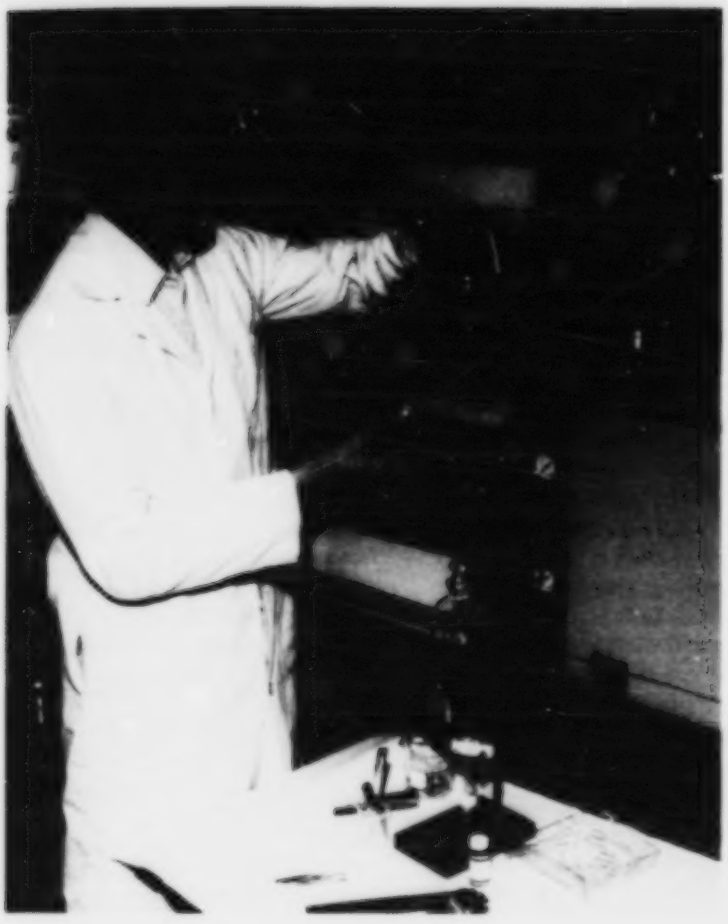
New modules for distribution system planning software

The first version of Hydro-Québec's distribution system planning software was no sooner completed in June 1989 than a series of improvements began. The purpose of this software is to help local planners select the equipment needed for distribution system expansion or upgrade. First, it allows overload and voltage drop problems to be detected for several years to come. Second, it enables planners to generate different system configurations automatically for a given year from user-selected switching points and then proceed to analyse these configurations.

Tests were conducted in a number of Hydro-Québec regions to determine possible additions to the software. This activity gave rise to a new project. As a result, not only were the existing functions of the program refined but a short-circuit-current calculation module was added. This is a significant improvement, considering the importance of short-circuit-current values for adjusting protection settings or for responding to customer requests.

The distribution planning and control engineers who are supervising this work plan to implement the new version of the software in the utility's administrative regions early in 1990. Special training will be provided for planners likely to use the program to verify the utility's criteria in the context of annual planning activities.

Méthodes numériques
(Numerical Methods)



Gas chromatography is the technique used to determine pentachlorophenol in wood samples taken from distribution poles.

ENVIRONMENTAL DIFFUSION OF PENTACHLOROPHENOL

A joint research program was recently initiated with Hydro-Québec environment specialists to study the diffusion mechanisms of pentachlorophenol (PCP). PCP is an active element used by Hydro-Québec to preserve the wood poles on its distribution system. The goal of the research is to determine the rate at which PCP diffuses into the environment, according to whether it migrates inside the pole, flows down it into the ground, escapes into the atmosphere, is washed away by rain, or diffuses and decomposes in the earth around the pole.

The project began in summer 1989 and should be completed by December 1992. The test results will be used to validate a diffusion model developed by Hydro-Québec's environmental protection department. The research involved calls for the development or adaptation of sophisticated analytical techniques that combine gas-phase chromatography and neutron activation analysis with liquid chromatography.

Chimie des matériaux
(Materials Chemistry)

Copper-aluminum connectors in a saline environment

Published experimental evidence and many reports on in-service failure suggest that one of the major problems affecting transmission and distribution systems, especially in coastal and urban areas, is the reliability of the connections between the various components of electrical equipment. The failure mechanisms of electrical contacts are complex, however, and current knowledge is insufficient to grasp them completely. The research project undertaken by contact specialists at IREQ for the Canadian Electrical Association is therefore aimed at establishing the relationship between the mechanical, metallurgical, electrical and tribological properties of copper-aluminum electrical contacts on the one hand and, on the other, the stability of the joint assembly and of the system as a whole.

First to be evaluated was the influence of these properties and the corrosive effects of a saline environment on the contact performance during normal current cycling and overload. Correlation factors will be established between the performance of laboratory-tested connectors under accelerated degradation conditions and field measurements on different types of connector under normal service conditions. It is expected to obtain useful information on the nature of contact interface degradation mechanisms in both cases.

The results obtained during these initial phases of the project will be used to draft installation, testing and maintenance guidelines.

Technologie des matériaux
(Materials Technology)

Corrosion in underground vaults

Distribution equipment installed in underground vaults (transformers, disconnectors, fuseboxes, etc.) is exposed to conditions that are particularly susceptible to corrosion. Research is now under way at IREQ and, under contract, at the Université de Sherbrooke, in an attempt to analyse the problem and formulate appropriate solutions.

IREQ has adopted two approaches: classification of materials by vulnerability and evaluation of the corrosion stability of the paints currently used or proposed. The materials were tested in solutions and at temperatures that simulated reality. On the basis of the results, the researchers were able to determine a galvanic series of different metals. To evaluate the paints, these were immersed in simulation baths at 25°C and 45°C. They were also subjected to impact tests to determine their mechanical strength. Following these tests, a recommendation was made regarding the type of paint to use for underground distribution equipment in the St-Laurent Region.

Meanwhile, members of the chemistry department at the Université de Sherbrooke are engaged in research on the corrosion and passivation mechanisms of tin, which is widely used to protect base metals such as copper or steel against corrosion. Tests have been performed in a buffer medium at pH 8 in the presence of bicarbonate, primarily to study the effect of chlorides, an aggressive agent found in underground vaults.

Chimie des matériaux
(Materials Chemistry)

Tests at the high-power laboratory

An important series of tests was performed on 21-kV metal oxide surge arresters. The first part of this complex test program consisted of rated discharge current withstand tests. It comprised four steps:

- injection of 20 impulse-current discharges, 10 kA peak, 8/20-μs waveshape, at 60-s intervals, with simultaneous application of a 21-kV, 60-Hz voltage at the arrester terminals;
- injection of two discharges, 40 kA, 8/20 ms, at 60-s intervals
- application of a 21-kV, 60-Hz voltage for 10 s;
- lastly, application of the maximum continuous operating voltage (MCOV), namely 17.6 kV, until thermal stability is reached.

Tests were then performed under internal-arcing conditions to verify that the arrester's pressure-limiting device was operating properly. This device is designed to transfer an arc produced by thermal runaway to outside the arrester housing, thereby preventing pressure build-up and explosion. Three different firing methods were used: with a fuse wire outside the metal-oxide blocks, with a fuse wire in the centre of the blocks, and thermal runaway.

The third method, thermal runaway, consists in heating the metal oxide blocks by passing a current of less than 100 mA using a variable-voltage source. Once the arrester reaches the required temperature, in other words when a voltage of approximately 15 kV manages to keep a current of 25 to 100 mA flowing, depending on the type of arrester, the variable-voltage source is disconnected. Four cycles later, the power source is applied to supply an internal-arc current of 8 kA rms symmetrical for 0.2 s and a 500-A arc current for 1 s.

Other tests were conducted to check the resistance of the metallic housing of different types of apparatus to internal pressure build-up and hot spots due to internal arcing. The test was performed at 35 kA rms three-phase at a voltage of 15 kV for 1 s. One of the methods used in this project consisted in placing black cotton indicators at all possible sources of escaping gases (joints, observation ports, doors); if the cloth did not catch fire, the test was considered successful.

Laboratoire Grande puissance
(High-Power Laboratory)

Capacitive-load breaking tests on a three-phase submersible base of the medium-voltage test station in the high-power laboratory.

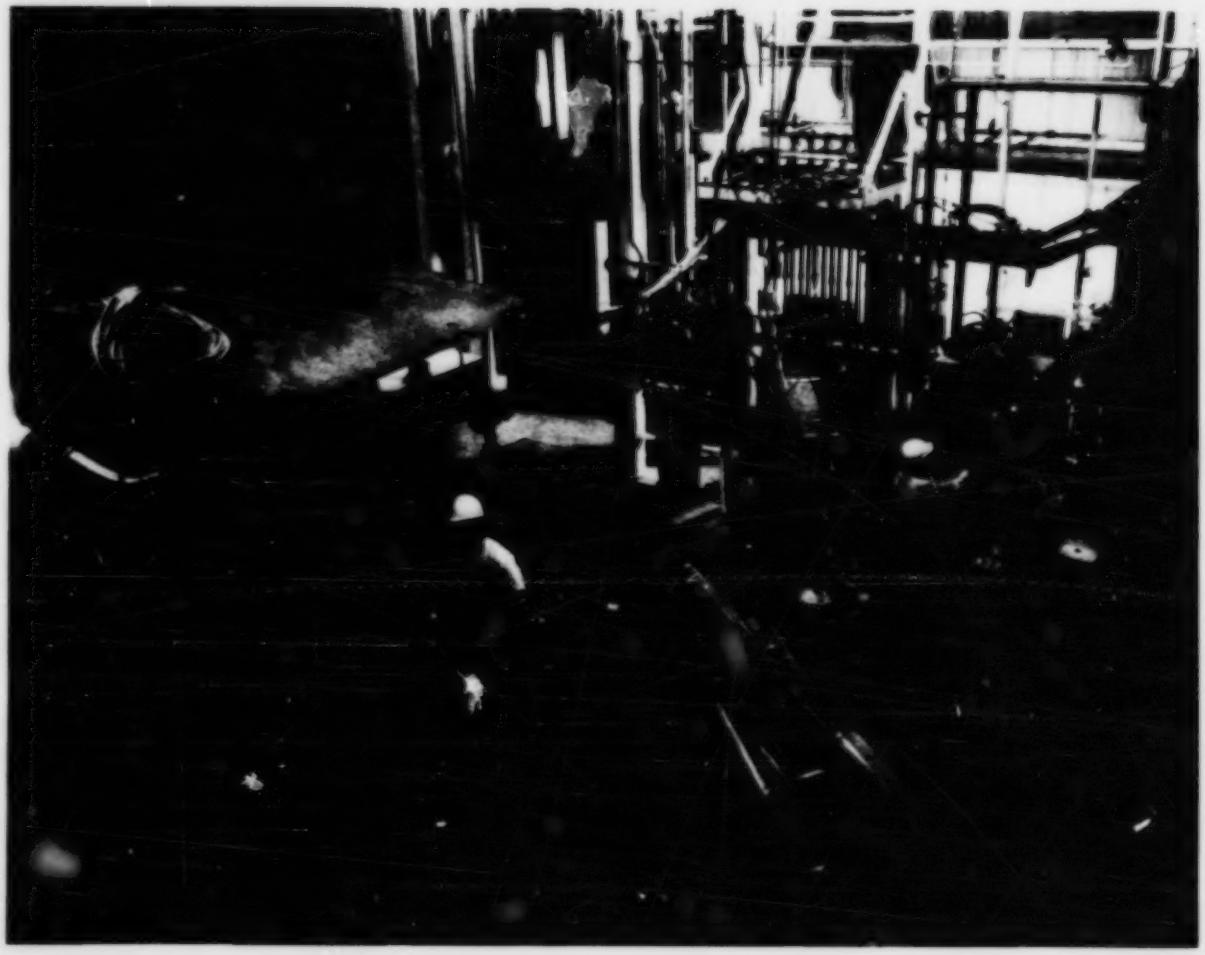
INDUSTRIAL APPLICATIONS OF ELECTRICITY

Many projects were undertaken at the electrochemical and electrical technologies laboratory in 1989 in fulfilment of the LTEE's mandate to develop and demonstrate new industrial processes that use electricity as their primary source of energy. Special mention might be made of the development of an integrated dual-energy heating system, the installation of prototype heat pumps with a nonelectric backup (PACANE), use of a 150-kW plasma torch for surface treatment of different materials, production of ethylene glycol by electrosynthesis and electrocoagulation of alfalfa.

Several new drying and heating devices were acquired during the year, making LTEE better equipped than ever to meet the needs of companies wishing to develop and incorporate new electrotechnologies in their industrial processes.

INDUSTRIAL PLASMA TESTING AND DEMONSTRATION

The LTEE plasma pilot plant, which now houses several plasma furnaces offering capacities ranging from 10 kW to 300 kW and designed for continuous operation, was used for various waste-processing tests. The first series concerned the processing of powdered metallic waste without pre-agglomeration. The Plasmacan furnaces proved particularly efficient for this type of processing. Meanwhile, preliminary tests were performed, very successfully, on the vitrification of ashes from incinerators of water treatment plants.



The high-temperature chemical reactor was also used with great success. The work here involved developing synthesis processes for continuous production of chemicals by reaction and quenching at temperatures over 1500°C. Hydro-Québec's industrial partner in this project is now investigating how to implement these processes. The 1-m³ reactor is equipped with a plasma torch with a capacity ranging from 10 kW to 200 kW. Other studies are planned on reactions taking place at 1000°C to 2000°C.

In the activities related to the opening of tap holes in arc furnaces, structural modifications had to be made to the torch so that it would resist the extremely high temperatures of molten refractory materials. To melt these materials, the torch must be able to penetrate holes that are only 6 cm in diameter but 50 cm deep and it must therefore resist the ambient temperature in the tap hole. Its reliability is now such that plant tests can be anticipated.

One of the mobile plasma units has been installed at a plant for demonstration tests on a process developed at LTEE. Tests on the production chain have confirmed that plasma-based surface treatment is faster than the currently used traditional technology. Morover, in contrast with the latter, the plasma process does not require pretreatment. The advantage of the plasma torch is that it produces much hotter gases than fuel torches and, hence, a stronger thermal shock at the surface of the material to be treated.

Lastly, an extensive study of plasma torch erosion was conducted with a McGill University team. The results already widely published, show that the erosion rate is influenced by both the arc speed and the current density. The former has been increased by doping the electrode while the latter has been reduced by selecting a suitable ambient gas. In addition, a new measuring technique has been developed for determining current distribution in the arc foot of an operational plasma torch. All these tests were conducted at a reduced current of 100 A at McGill University. Other tests at high currents (1500 A) will be performed at LTEE test facilities.

Plasmas industriels
(Industrial Plasmas)

LTEE facilities for research into the industrial applications of plasmas.

ELECTROCOAGULATION OF ALFALFA

As part of a project to promote the nutritional value of alfalfa, the electrocoagulation of white proteins was tested using an electrodialysis process. This project was initiated jointly by the Centre de déshydratation Nord/Sud (CDNS), (North/South Dehydration Centre) and the Société de développement agro-alimentaire de la Mauricie, an agro-food development company in the Mauricie region of Québec. The tests, believed to represent a world first, drew upon the expertise of both LTEE and the Canadian government's Food Research and Development Centre (FRDC) in Saint-Hyacinthe and were very successful.

The CDNS has now turned its attention to the transformation and dehydration of alfalfa as fodder. To this end, the company is planning to promote the by-products of the green liquid that results from pressing and, in particular, the white protein it contains. The high selling price ($2,500/tonne) of the protein, which could possibly be used for human consumption, represents a high added value compared to the conversion cost.

The FRDC, for its part, is working on a laboratory study launched two years ago to investigate protein extraction and purification processes. LTEE experts were invited to contribute to the development of a coagulation process for white proteins. The conventional approaches adopted for industrial coagulation of food proteins such as casein and soya bean protein isolates involve adding an acid solution to the protein solution until the isoelectric point is reacned (pH 4.5). This process can be applied to alfalfa juice but the white protein the juice contains is highly sensitive to the excessive acid doses to which it is exposed.

Electrocoagulation is seen as a promising alternative: it is in fact a more delicate process, which means that the protein substance is less apt to degenerate. The process tested at LTEE consists in electrodialyzing the brown solution which contains approximately 2% by weight of protein and 0.15 g of salt per litre (expressed in KCl equivalent).

When the voltage between the electrodes of the module reaches a high enough value, the alfalfa solution acidifies, and the acidification process can be controlled. Electrodialysis not only provides an acid medium suitable for protein coagulation but also allows the salts to be extracted, which is another essential stage in the overall white-protein extraction and purification process.

These preliminary tests were performed in semi-continuous mode using filter-press type electrochemical cells. On the strength of the positive results obtained, the researchers plan to initiate a project to optimize the new process in 1990.

Chimie et Électrochimie industrielles
(Industrial Chemistry and Electrochemistry)

ORGANIC ELECTROSYNTHESIS

A three-year project aimed at developing and marketing an ethylene-glycol and terephthalic acid manufacturing process was launched in 1989. Conducted jointly with Hydro-Québec's industrial markets group and various external partners, this project comes on the heels of a series of market-prospecting studies on the potential applications of electricity in the synthesizing of commercially promising products.

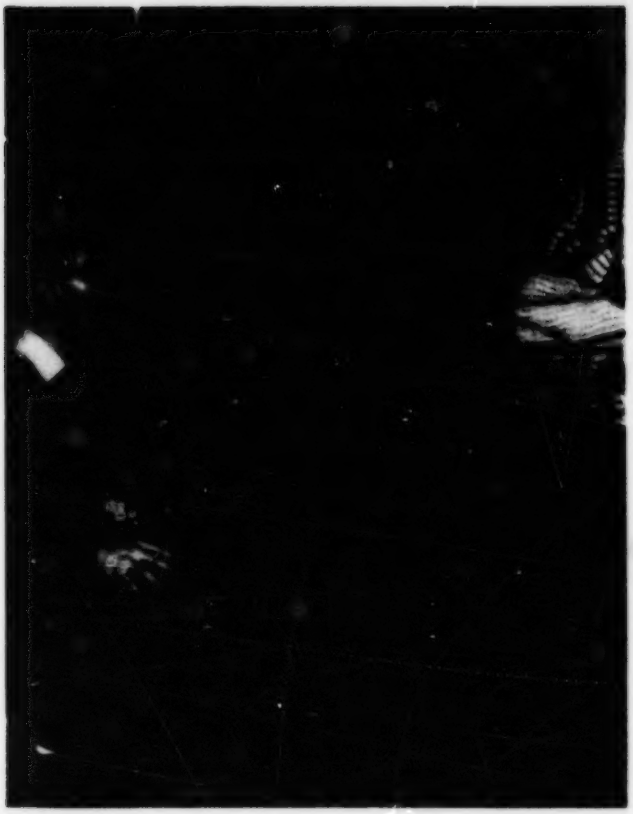
The aim of the first phase of the program is to validate the laboratory results on prepilot test benches. These facilities are equipped with filter-press type electrochemical cells offering electrode surfaces of 100 cm^2 and 400 cm^2 and current-density levels of the order of 5 kA m^2. The tests also provide an opportunity to determine the optimum operating conditions and parameters of the processes used, from both the technical and the economic points of view. In addition, endurance tests will be performed which should furnish the data needed to select the best reactor construction materials.

The prepilot tests conducted in 1989 confirmed on an industrial scale, for the first time, the results obtained in the laboratory and allowed significant improvements to be made to the technology. In some cases, an efficiency of over 90% was attained, as well as a threefold reduction in the reagent residence time in the electrochemical reactor.

The next step involves a pilot program on a semi-industrial 5-kg h test bench. Now under construction, the test bench will be fitted with electrochemical cells having an electrode surface area of 4000 cm^2. Meanwhile, economic and marketing studies will be regularly updated to ensure the electrochemical process maintains its competitive edge.

Chimie et Électrochimie industrielles
(Industrial Chemistry and Electrochemistry)

Validation of an industrial electrosynthesis process for the production of ethylene glycol.



Forty-eight prototypes of the integrated dual-energy heating system developed at IREQ have been installed in customers' homes for evaluation.

DEVELOPMENT OF AN INTEGRATED DUAL-ENERGY HEATING SYSTEM

The original objective of the residential dual-energy heating program was to promote electricity sales without increasing the power system peak. This objective has been achieved, and the technical and commercial aspects of this program are now well in hand, to judge from the satisfaction expressed by Hydro-Québec's customers.

There is a risk however that the existing dual-energy stock could be undermined. Customers replacing their oil furnaces now tend to choose an all-electric system rather than adopt the new dual-energy system. Hydro-Québec has therefore devoted a major effort to developing a high-quality integrated dual-energy heating system in an aim to curb this trend.

In the new heating unit, the two energy sources, oil and electricity, are integrated at the plant in order to simplify the components and the operation. The automatic changeover function, which switches from one mode to another in case of failure, ensures greater availability of heating. The control system has been fine-tuned to increase the comfort level whatever energy mode is operating and however low the outdoor temperature drops.

Dettson and Les Industries FP have produced 48 prototypes which were installed in fall 1989 in the homes of Hydro-Québec customers in the Mauricie Region for testing. The purpose of this two-year series of tests is not only to verify the reliability of the new concept but also to gather feedback from customers and from the companies responsible for installing the equipment. It will then be possible to establish the design criteria and operating characteristics of future integrated dual-energy heating systems. Thus Hydro-Québec will be in a position to offer its customers a quality product while maintaining or even increasing its residential dual-energy heating stock.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

HEAT PUMP WITH A NONELECTRIC BACKUP

LTEE has received a mandate from the utility's Québec markets group to develop a heat pump with a nonelectric backup in an attempt to reduce the energy demand at peak periods.

The main features of PACANE, as the new heat pump is known, are its variable-speed compressor, which allows the heating demand to be adjusted, use of a second heat exchanger outdoors to recover the combustion energy of the propane backup, and the introduction of microcomputer-based control of the equipment in terms of energy requirements. The combination of these three features contributes to a higher performance than that of commercially available products.

Two local firms, Maxtemp Thermo Confort and Les Industries FP, have been awarded the contact to manufacture the new heat pump and some twenty customers in the Trois-Rivières area of Québec have been selected for testing the model under normal operating conditions. The test program, due to be completed in June 1990, will provide the parameters required for developing commercial programs for installing the new heat pump model.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

PROJECTS FOR INDUSTRY

Throughout the year, LTEE provided technical support to electrotechnology engineers in Hydro-Québec's administrative regions, as well as to the commercial attachés in the utility's Québec markets division, by evaluating various industrial processes. The goal was to upgrade those processes, both from the energy viewpoint and with regard to the quality of the finished product.

The infrared drier was used to determine the drying parameters of materials ranging from silty marn and calcite to limestone and ilmenite.

Many studies, backed up by laboratory tests, were carried out in various fields of application including high-frequency induction smelting of ferroalloy fines; induction heating of calander rollers on the PAPRICAN laboratory paper machine; design and manufacture of an induction-type pasteurizer for milk processing; microwave pyrolysis of rubber; microwave drying of transformers; and microwave sterilization of hospital laundry.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

NEW FACILITIES FOR LTEE

Several additions were made to LTEE facilities during the year, including an immersion heater/evaporator which is due to be tested for Hydro-Québec and its industrial customers.

This 75-kV machine, supplied from a three-phase 600-V source, is mounted on a mobile platform together with all the required accessories so that it can be easily moved as needed during factory tests. The flow rate of the fluid to be heated can reach 15 l/min in the liquid phase; the maximum operating temperature and pressure are 200°C and 1350 kPa respectively. The machine is equipped with a microprocessor for process control and for acquisition of the data needed to establish the energy and heat balance. All parts in contact with the liquid are made of nonoxidizable materials, allowing the machine to be validated with a wide variety of fluids.

The immersion heater/evaporator offers an alternative to electrical resistance heating for all liquids, especially those sensitive to heat. The power applied to the heat exchanger is transferred by means of a magnetic field, a technique which ensures uniform power distribution across the entire surface of the exchanger. This feature, combined with a rapid control response, stands the newly developed technology in good stead to make a breakthrough in industrial uses.

Among other additions in 1989, mention could be made of two furnaces, one of 6 kW, the other of 2.5 kW; a high-temperature oven with temperatures capable of exceeding 1750°C; an environmental chamber offering full control of the test conditions; a 100-kW fluid heater; and a pasteurizer, which was designed in cooperation with the Université Laval.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

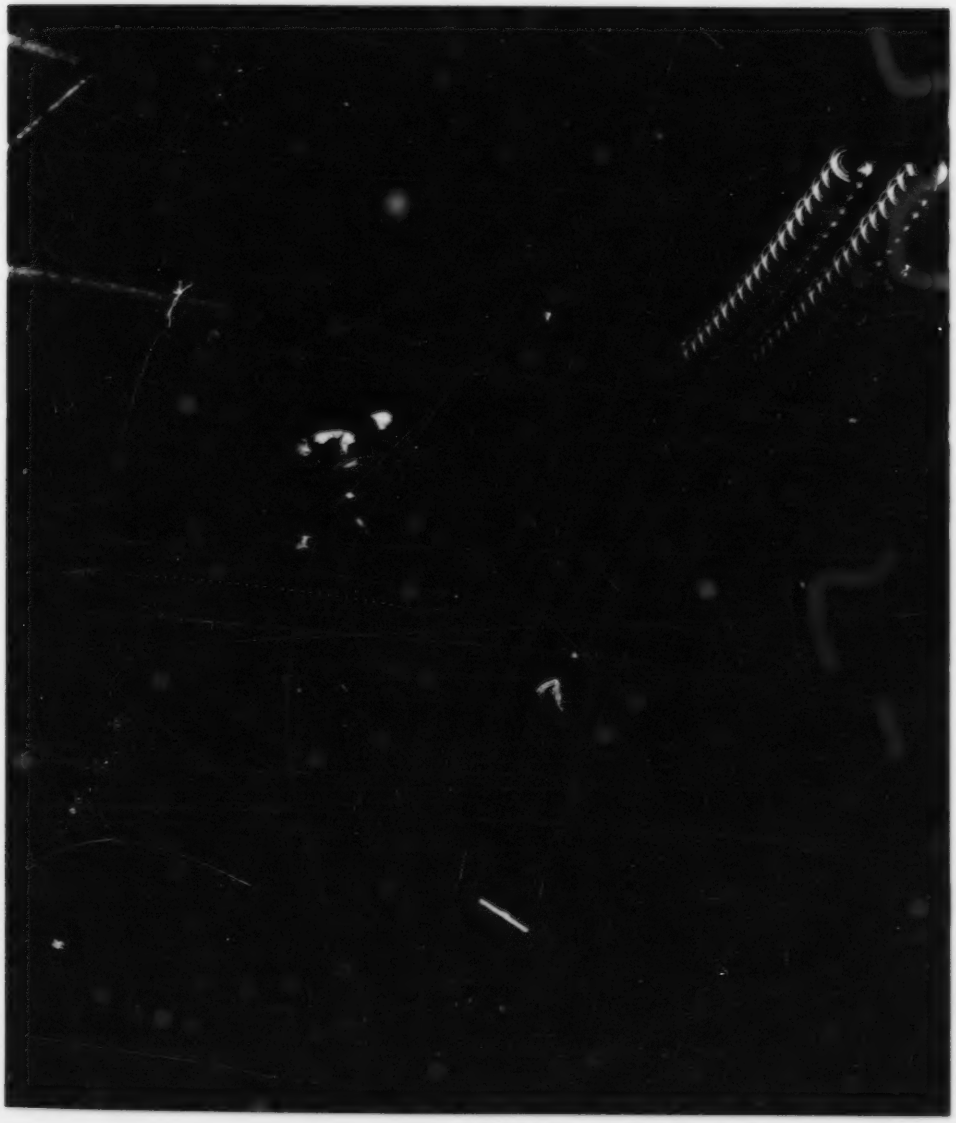
MATERIALS, TEST TECHNIQUES AND MEASURING DEVICES

Development work on a puncture detection device for high-voltage line insulators led to the production of a commercial prototype this year. Meanwhile, in the context of the HVDC cable test program, a system for measuring the temperature of energized cables has been developed. Work was pursued also on the design of a device for analysing the leakage current on the surface of insulators while a joint project between Hydro-Québec and the École Polytechnique de Montréal was launched to study microwave drying for bushings.

The past year saw the development of techniques for the detection and analysis of methylmercury in water stored in hydroelectric reservoirs. Shunts for testing generators at the power plant have also been developed, in addition to a high-speed data acquisition system. Lastly, work continued on the expert evaluation of insulating oils used in electrical apparatus.

PUNCTURE DETECTOR FOR CAP-AND-PIN TRANSMISSION LINE INSULATORS

A first commercial prototype of an in-house designed and developed probe for detecting punctured insulators on power lines has been manufactured by Positron. Built in accordance with the operating requirements specified by Hydro-Québec's apparatus specialists, the prototype is now undergoing field tests, which are due to be completed in the near future.



Commercial prototype of probe for detecting punctured insulators developed in collaboration with Positron.

To detect the presence of punctured units, the probe measures the local electric field along the suspension insulator strings and records all variations; the field tends to be appreciably lower near faulty units. The Positron prototype marks an improvement over the first device developed at IREQ in that all the electronic components are now housed inside the probe. The laboratory prototype, on the other hand, comprised two parts, one of which had to be installed on the ground at the foot of the tower; this arrangement called for a frequency-modulated transmission link to carry the recorded data to the unit on the ground.

If the tests on the new prototype are satisfactory, Hydro-Québec will purchase a sufficient number of units to equip all line crews responsible for checking porcelain insulators on the transmission system.

Two patents have been granted for this device; one in the United States dated July 26, 1988, the other in Canada, dated September 26, 1989.

Mesure et Informatique
(Measurement and Data Processing)

RESEARCH ON INSULATING OILS

Following a series of major faults on power transformers at La Grande 4 generating station, regional operators and Hydro-Québec's apparatus specialists turned to IREQ for an expert evaluation of the properties of the insulating oils used. A ferrographic analysis was therefore undertaken and the results of dissolved-gas analyses were interpreted in an attempt to assess the quality of the transformer insulation.

The ferrographic analysis revealed the presence of fine particles of aluminum due to mechanical abrasion inside the oil coolers. Interpretation of the dissolved-gas analysis results, on the other hand, allowed a hot spot to be diagnosed which, upon inspection, turned out to be caused by overheating of the low-voltage connections.

Câbles et Isolants
(Cables and Insulation)

LEAKAGE-CURRENT ANALYSIS

Development work on a leakage-current analyser was completed this year. Designed to measure current flowing at the surface of insulators, this device provides a means of assessing the performance of surge arresters, bushings and other transmission line equipment under natural contamination. Every second, the analyser measures the peak current, the voltage and the temperature to determine whether flashover has occurred. The housing consists of a shielded steel box which is thermally insulated, heated and air-conditioned.

The analyser comprises six STD bus cards. One of these is a PC card without a screen, a keyboard or disk drive, the floppy disks having been replaced by electronic disks. An RS-232 link or a modem provides for communication with the user. The analogue-to-digital converter has a 12-bit resolution. One card also holds the analogue measuring circuits (peak current detectors, rms/DC voltage converter, temperature measurement amplifiers).

The DOS 3.3 operating system is used. The software is designed in BASIC (QuickBasic 4.5 version) and controls data acquisition, processing and storage, communication (via a modem) with the user, and data transfer in the form of tables. Peak currents, histograms and other data are saved in files and can be displayed in the form of daily, monthly or yearly tables. The data presentation format allows the Lotus spread sheet to import files for creating graphics.

This development work is part of a project undertaken for the Nova Scotia Power Commission under a Canadian Electrical Association contract.

Lignes aériennes
(Overhead Lines)

MICROWAVE DRYING OF BUSHINGS

The bushings used for high-voltage equipment comprise a conductor covered with several layers of insulating paper. The insulation, together with part of the conductor itself, is housed in a porcelain cylinder which is tightly sealed and filled with oil. Under operating conditions, however, moisture can seep into the bushing through the joints of the housing or cracks in the insulation, and affect the latter's dielectric properties. The bushing must then be removed and taken to the shop for drying.

Since the hot-air drying process currently used for this purpose is lengthy and costly, IREQ researchers have designed a fast and efficient microwave drying device in an attempt to reduce the costs and drying time. The water in the insulation can now be heated to produce steam which can then be extracted with a vacuum pump and a condensation system. Tests on the new process have been conclusive.

Although the device was specially conceived for 120-kV bushings, the technology applies equally well to paper oil-impregnated bushings designed for voltages up to 120 kV. This project involved collaboration with the École Polytechnique de Montréal.

Câbles et Isolants
(Cables and Electrical Insulation)

NEW 25-OHM SHUNTS FOR GENERATOR FIELD TESTS

In response to a request by the testing and technical appraisals team in Hydro-Québec's Maisonneuve Region, a 25-ohm shunt has been designed and built for short-circuit tests on generators at the power plant. The new shunt can measure a 70-kA short-circuit current of 2-s duration with an accuracy of 0.5%. It has been designed to withstand electromechanical stresses associated with peak currents of up to 200 kA.

Using a parabolic-profile compensation technique developed at IREQ, the researchers have achieved a response time of 5 ms. With this technique, the gain is 20 times higher than that of a non-compensated shunt – without any significant increase in the production cost.

The new shunts were made by IREQ's technical services personnel and electronics specialists. The short-circuit tests and scale-response measurements were performed at the high-power laboratory.

Mesure et Informatique
(Measurement and Data Processing)

Microwave device for drying 120-kV bushings.

METHYLMERCURY DETECTION IN RESERVOIRS

Work has begun on developing a low-cost technique for rapid detection and measurement of methylmercury in reservoirs. In its natural state in the environment, mercury (or inorganic mercury) is usually bonded to particles in suspension or found in sediments. When a reservoir is built for hydro power, bacteria convert inorganic mercury into a toxic form, methylmercury. This mercury derivative, whose concentration increases as it passes along the food chain, represents a health hazard. IREQ's study, which began early in fall 1989 and is scheduled to last two years, comprises two parts: one electrochemical, the other chromatographic.

The objective of the first part is to develop a rapid and reliable electrochemical analysis technique using small samples of just a few millilitres. The initial step will be to optimize the physicochemical conditions of the samples: pH, temperature, nature and ionic strength of the supporting electrolyte, etc. The next step will be to develop the analytical technique itself, in which the substance present in the sample will first be adsorbed at the surface of a detector and then quantified. The development work calls for a study of various complexing agents as well as the main sources of natural interference present in the environment. The electroanalytical technique must be inexpensive, rapid (less than 1 h), and usable directly in the field. In addition, it must be applicable for measuring both methylmercury and inorganic mercury.

The second part of the study, conducted jointly with the Université de Montréal, is aimed at improving existing chromatographic detection techniques. These consist in separating the element to be detected from the other elements present in the sample. Work so far shows that plasma-atomic emission detection has certain advantages over the widely used electron-capture detector. Although the two approaches offer virtually identical sensitivity, their selectivity is very different: the first traces mercury atoms specifically, whereas the second detects all chlorinated compounds, which are present in large numbers in nature and can therefore interfere with the analysis. It is expected that plasma-atomic emission detection will likely be used for the methylmercury measurements planned at Hydro-Québec.

Chimie des matériaux
(Materials Chemistry)

DEVELOPMENT OF A HIGH-SPEED DATA ACQUISITION SYSTEM

A new large-capacity, high-speed data acquisition system has been developed to meet the needs of various TAI research departments. The system uses a SUN 4 computer and 16-megabyte memory cards and includes an interface for memory management.

This interface receives data from a converter and transfers it to the memory in such a way that the latter serves as an endless loop: when the memory is full, data entry starts again, and so on, until a trigger signal reaches it from outside. Thus a volume of pre- and post-event data is stored (opening or closing of a circuit breaker, for instance). The total storage space amounts to 8 million samples, collected at a rate of one million per second.

The technique has the advantage that the data do not need to be transferred but can be read directly from a work station.

The same group of researchers has also developed two cards whose basic function is memory management. The memory can be divided into a number of segments (up to 1000) to gather data on a series of consecutive phenomena. It also allows users to determine the amount of data to be stored in memory before and after the trigger signal. To achieve that capacity, ten interface cards have been installed in parallel with ten memory cards while an integrated circuit upstream from the interfaces acts as a dispatcher.

The system intended for the Maisonneuve Region's team of testing and technical appraisals experts – who study power system phenomena in real time – has an acquisition capacity of ten million samples per second. To achieve this goal, the system designers put ten interface boards in parallel with ten memory boards. Upstream from the interfaces, they incorporated another circuit to act as a dispatcher.

Two other TAI departments are now using a similar acquisition system, although the architecture is slightly different. The high-power laboratory uses 32 interfaces and the same number of memory cards for a total of 32 billion samples per second, while the Service Études du réseau, where four systems are now in use, has turned to a Preston multiplexed acquisition unit which has a 128-channel capacity. In the near future, the high-voltage laboratory will also be equipped with a similar system.

Mesure et Informatique
(Measurement and Data Processing)

A new system using an infrared light beam was developed to measure the temperature during high-voltage cable tests.

TEMPERATURE MEASURING SYSTEM FOR ENERGIZED CONDUCTORS

In view of the aging tests soon to be performed at the high-power laboratory's undergound-cable testing facility, a new system has been developed for measuring the internal temperature of the conductors. The aging tests consist in subjecting three cable prototypes to a voltage of approximately 600 kV DC and a current of the order of 1 kA, under climatic extremes (–40°C to +35°C) for several months. The temperatures to be measured range from 0°C to 100°C.

One main difficulty was to select an efficient means of transmitting the measurement data to ground level. The final decision was to use an infrared optical link, which has the advantage of not affecting the test object insulation. It also has natural immunization against electromagnetic interference.

The temperature is measured by thermocouples at different locations along the length of the conductors, inside the central oil channel. The data is collected by a multichannel acquisition unit installed near the top of the insulator, in a shielded case, and powered from solar panels. Infrared transmission then carries the data to receivers inside the control building and, ultimately, to each control microcomputer. The temperature of each prototype is read to the nearest degree Celsius at 1-min intervals.

Mesure et Informatique
(Measurement and Data Processing)

DEVELOPMENT PROJECTS

Under an agreement between the Québec government and the Commission of European Communities, Hydro-Québec has undertaken a feasibility study on the production, intercontinental transportation and utilization of electrolytic hydrogen produced in Québec. In the field of polymer-electrolyte (ACEP) batteries, performance optimization studies continue and negotiations are under way with a view to creating a joint venture for research, development and commercialization of this technology.

In other areas, specialists are installing a microcomputer-controlled system for automation of power system manag. ment functions at a Hydro-Québec distribution control centre. Development and implementation of expert systems are marking good progress and, lastly, a laboratory prototype has been developed for the treatment of cystic fibrosis.

INTERCONTINENTAL HYDROGEN TRANSPORTATION PROJECT

The Commission of the European Communities and the Québec government have agreed to carry out a joint feasibility study on the intercontintental transportation of energy in the form of hydrogen. Hydro-Québec, which is responsible for managing the Québec aspects of the project, has formed an association with the German firm Ludwig-Bölkow-Stiftung (LBS), its European counterpart. Some twenty industrial partners are contributing either technically or financially to the project.

Photo : Air Liquide Canada

The $4.2-million study involves a technical and economic evaluation of a full cycle – production, transportation and utilization of hydrogen. According to the forecast scenario, a 100-MW electrolysis plant would be built at Sept-Îles on the north shore of the St. Lawrence River. The hydrogen produced there would be shipped to a European receiving and marketing centre in Hamburg. Two agents have been proposed for transporting the fuel: liquid hydrogen and toluene-methylcyclohexane. Two other options have also been summarily assessed for comparison, ammonia and metallic hydride. With regard to utilization, liquid hydrogen could be used to fuel airbuses and LBS and Benz rapid transit buses. Moreover, Daimler-Benz in collaboration with BMW have produced an experimental motor that runs on hydrogen.

Although this form of energy is not competitive in the short term – its cost is currently twice that of more common fuels – it has multiple advantages that could make it the energy of the future. Contrary to hydrocarbons, for example, hydrogen has less impact on the environment. It is also a renewable fuel which can be produced from a resource that is equally renewable, hydroelectricity. The abundance of water power in Québec and the expertise acquired in the field of electrolysis give the province a unique opportunity to become a world leader in this field.

A final report on the feasibility study will be issued in mid-1991 with a recommendation of whether to proceed with or postpone the pilot phase of the project.

Projets de développement
(Development Projects)

Electrolysers at the Hydrogen/Cl plant in Bécancour, Québec.

ACEP DEVELOPMENT AND MARKETING

As research and development work on the polymer-electrolyte ACEP battery progressed throughout 1989, efforts to market this technology continued. IREQ's materials chemistry team thus pursued its objective to optimize low-temperature batteries while industrial chemists and electrochemists at LTEE, in cooperation with local engineering firms, started work on the commercial development of a lithium thin-film fabrication process.

Negotiations aimed at creating a joint R&D company with an industrial partner have now reached an advanced stage and should produce an agreement in 1990. The short-term goal of this joint company will be to market small ACEP batteries but in the longer term it will be responsible for the development and marketing of large ACEP batteries intended for electric vehicles. Research continues with a view to resolving materials-related problems that curtail the service life of ACEP batteries.

Projets de développement
(Development Projects)

DEVELOPMENT OF A DEVICE FOR TREATMENT OF CYSTIC FIBROSIS

A joint project with Bell Canada has resulted in the development of a new device for the treatment of cystic fibrosis. An articulated support contributes to the independence of people with this illness by enabling them to administer their own treatment.

Cystic fibrosis affects the respiratory tracts. It causes an accumulation of mucus in the bronchial tubes which produces bacteria and involves a very high risk of infection. There is a method for decongesting the pulmonary lobes that provides the patient with some relief, postural draining as it is known, but its application calls for therapeutic devices that are either heavy and noisy or debatable in terms of efficiency. Moreover, none of them can be easily operated by the patient.

In response to a request from the Association québécoise de la fibrose kystique, work began on the development of a low-cost device that is easy to use. Rejecting the use of robotics as too expensive and unable to provide the necessary safety guarantees, the research team turned to proven techniques to develop an articulated arm to which percussion devices can be attached and which the patients can operate themselves. The laboratory prototype was successfully tested by cystic fibrosis patients who found the technique easy to learn.

The research team has since developed a prototype which combines percussion and vibration. It allows patients to select the intensity of treatment they want and, in addition, offers a substantial reduction in noise level.

The project is now in its final stage and steps have been taken to develop industrial prototypes and put them on the market.

Électronique
(Electronics)

TELEROBOT FOR DISTRIBUTION SYSTEM MAINTENANCE

A project has been launched at the request of the Vice-présidence Production, Transport et Distribution to produce the first prototype of a telerobot for distribution system maintenance by early 1991. In the initial stage of this project, which comprises the evaluation of different concepts and selection of the design offering the greatest technical, economic and commercial potential, CAE Electronics will act as consultant and various suppliers, recognized for their quality products, will be approached for comments.

As soon as the design has been chosen, work will begin on the development and demonstration of the prototype. The telerobot will comprise two articulated arms to carry out most of the tasks involved in distribution system maintenance with a control station mounted on an aerial platform.

Projets de développement
(Development Projects)

Bell Canada and IRI researchers have developed a prototype device for the treatment of cystic fibrosis.

Implementation of the computer-based automation system for a distribution control centre continued this year. A feasibility study was conducted and a prototype built for the City of Los Angeles.

AUTOMATION OF A DISTRIBUTION CONTROL CENTRE

Work continued on a pilot project initiated in 1988 to implement in-house developed computer programs for automating power system management functions at St-Laurent distribution control centre. The authorization and hold-off management software as well as the switching scheme planning software have now been integrated and digitization of medium-voltage lines in the north and south sectors of Montréal has begun.

In addition, equipment has been purchased and software developed for the following tasks:

- fitting Hydro-Québec trucks with terminals to allow work crews to communicate with the automatic control centre;
- building a mimic board providing immediate access to a complete view of the status of the power system for management purposes.

Under agreements with various users both inside and outside the utility, tests have been performed with a view to determining and developing the following related applications:

- real-estate mapping pilot project using a scanner technique and imaging and database interaction software, which is yet to be developed (Hydro-Québec, Direction Propriétés immobilières)
- automated planning of meter-reader circuits based on the utility's customer-accounting management system (Hydro-Québec, Laurentides Region);
- analysis and proposal for implementation of an emergency telephone call distribution system (Fire Protection Department, City of Montreal).

In 1989, TAI stepped up its market-prospecting activities to promote its management, interactive and instant imaging (M3I) products. Various techniques were designed, including a portable PC demonstration unit, a video, pamphlets and brochures, and a showroom was set up at the St-Laurent regional headquarters.

Detailed presentations of the M3I products were consequently made at several specialty conferences and exhibitions in Canada and in the United States and, also, at the 14th Congress of the World Energy Conference held in Montreal in September 1989.

The outcome of all these efforts was a commercial breakthrough in the form of a contract from the Los Angeles Department of Water and Power to study the feasibility of installing the trouble call system (START) module and support software.

Projets de développement
(Development Projects)

EXPERT SYSTEMS

The exploratory studies on expert systems, initiated at Hydro-Québec in 1987, demonstrated the vast potential of this technology and led to the creation, the following year, of the Expert Systems Task Force. The mandate of this task force is to design, develop and implement expert systems in the utility's strategic sectors, namely power generation, transmission and distribution.

As a result of the task force's work, several expert systems have been introduced and now form part of routine activities. These include:

- TRANSEPT-CA: a pilot expert system used for the preliminary design of an AC transmission system. The prototype has been validated by users and a final model is now under development.
- EXSEMBLE: an expert system used for drawing up a master plan for the design of a type II 120-25 kV substation. The prototype has already demonstrated the validity of this approach and Hydro-Québec is now ready to produce systems for the user.
- DIALEXT: an expert system for alarms management in regional control centres. A pilot model has been produced and sent to the Maisonneuve Region for validation.

The following projects are at the prototype or pilot stage:

- LANGAGE: a generalized expert system for processing alarms at regional control centres, substations and generating stations. LANGAGE is in fact a programming shell which will offer significant savings in resources once the concept has been incorporated into Hydro-Québec's power system control procedures. It will also contribute to enhancing power system reliability.
- SUBAREX: an expert system used for dam monitoring which will allow more thorough evaluations of the safety of the utility's dams.
- TRANSEPT-CC: a prototype expert system for preliminary design of DC transmission systems, which will ultimately be combined with the AC version to form a software package.

In view of the new ground it is treading with this technology, the task force lays great emphasis on training. Courses have therefore been given to corporate vice-presidents and some of their subordinates. In addition, a two-semester postgraduate knowledge engineering course has been developed with a Montréal computer research centre, CRIM, for some 20 specialists.

The first International Symposium for the Demonstration of Expert Systems in the Electrical Industry was organized and held in Montréal on May 7-12, 1989. Over 200 delegates from 16 countries scattered across five continents attended. Twelve organizations from Canada, France, Finland, Japan, Norway, Spain and the United States presented 19 demonstrations, 17 of which were in real time. These live presentations were made simultaneously on giant screens using digital projectors, an imaginative new formula for international conferences. The Symposium proved that expert systems are viable and of benefit to the electrical utility industry.

Projets de développement
(Development Projects)

LONG-TERM PROJECTS

Activities related to the superconductivity project in 1989 were aimed mainly at improving the ceramics manufacturing processes in order to obtain superconducting materials with a higher current density. As for nuclear fusion, the research team took advantage of the tokamak being dismantled for the installation of new internal components to perform a detailed analysis of the results yielded by the first test series and to improve the performance of the various diagnostics for which it is responsible. Two members of the research team have been seconded to Europe to take part in the multinational ITER project, which involves the design and construction of a fusion reactor.

Work continues in the field of telerobotics, with the main focus this year on the development of a control system adapted to a telerobotics context. A project on the catalytic conversion of methane was completed.

SUPERCONDUCTIVITY

Last year saw considerable action in the field of superconductivity at IREQ. Research and experimental work on superconducting materials included a study of various ceramics from the point of view of their structural characteristics and possible correlation with their superconducting properties. The ceramics investigated are mixed oxides composed of yttrium, barium and copper. The primary objective of this research is to improve the manufacturing processes in order to achieve a higher critical current density. To this end, a SQUID magnetometer, a superconducting magnet with a magnetic flux density of 11 teslas, and critical-current-density measuring devices have been purchased and put into service.

Measurement of the critical current density of superconducting materials.

Although the critical temperature of superconducting materials is important, their characteristic current density is even more so if the materials are to be economically and technically viable. In fact, the critical current density must reach 10 to 100 kA/cm^2 in moderate magnetic fields.

A study is soon to begin with IREQ's numerical methods and with power system studies experts to investigate the use of superconducting magnetic energy storage (SMES) batteries as a means of stabilizing the power system, similar to static and series compensators. The first part of this project will comprise a simulation study and a cost assessment and, if the results are conclusive, work will begin on the design and development of a prototype for testing purposes.

Technologie des matériaux
(Materials Technology)

Catalytic conversion of methane into ethane and ethylene

In 1989 work was completed on a study aimed at determining the reaction of methane with unstable oxygen contained in various catalysts that have reducible-oxide components. The reaction should normally produce higher hydrocarbons, especially ethane and ethylene, but it is difficult to limit the total oxidation of methane into carbon monoxide and dioxide. A series of catalysts were therefore tested in catalytic reactors to determine their activity and selectivity. The results led to the development of a particularly active and selective catalyst: $Li_2O/PbO/Pr_6O_{11}$. The next step was to assess the influence of the temperature, the CH_4/O_2 ratio and the residence time on this catalyst. In addition, a number of catalysts including lithium, lead, praseodymium and oxygen were analysed by thermogravimetry (TGA), X-ray diffraction and XPS for characterization purposes. This project was performed in cooperation with CANMET (Canada Centre for Mineral & Energy Technology) and Gaz Métropolitain.

Meanwhile, fundamental research was performed at IREQ to determine the oxidation-reduction properties of several catalysts. The findings of this study, which is part of a doctoral thesis for the Chemical Engineering Department of Université Laval, revealed that the catalysts' activity and selectivity are both related to the unstable-oxygen content. In-depth TGA and XPS analyses of the catalyst Li/Pb/Pr/O and its precursors, Pr/O and Li/Pr/O, provided valuable insight into the mechanisms involved and the data required to propose a reaction scheme.

Chimie des matériaux
(Materials Chemistry)

Telerobotics

A new research project with the Centre de recherche informatique de Montréal and McGill University was launched this year to develop a control system adapted to a telerobotics context.

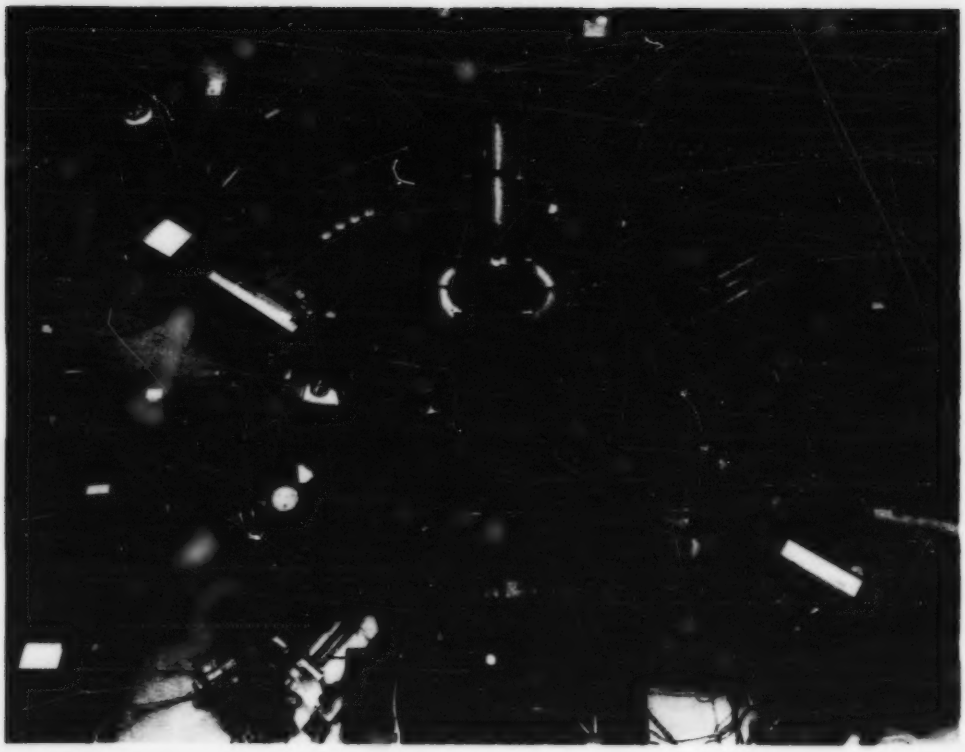
The results of a feasibility study of robotized maintenance work on an underground power distribution system revealed the difficulty of automating maintenance tasks without radical modifications to existing equipment and construction standards.

IREQ's robotics team also contributed to the drafting of technical procurement specifications for a remote manipulator for the Direction Distribution. Another project involved testing a force wrist for the real-time guiding of the laboratory test robot.

Various applications for mobile robots have been evaluated, including the positioning of sensing devices on live electrical equipment and inspection of the utility's Daniel Johnson dam.

Lastly, a major effort was devoted to the planning of an applied research program on robotics. The program takes account of corporate needs, available expertise and potential spinoffs on parallel activities performed by other Hydro-Québec departments and the utility's industrial partners.

Électronique
(Electronics)



The Varennes tokamak, which remained dismantled all year for the installation of internal components, will be put back into service in spring 1990.

Magnetic Fusion

Canadian Centre for Magnetic Fusion

Since 1988, Hydro-Québec's research into magnetic fusion has been conducted under the umbrella of the Canadian Centre for Magnetic Fusion (CCMF), an independent organization created jointly by Hydro-Québec, Atomic Energy of Canada Limited and the Institut national de la recherche scientifique, the major financial backers.

In keeping with its mandate to operate the Varennes tokamak within the framework of Canada's national fusion program, the CCMF contributes – to the fullest extent of its scientific expertise – to the development of nuclear fusion. This new energy source is not only promising but has a minimal impact on the environment. The CCMF's research program and facilities must therefore be adapted to the objectives: namely the study of so-called "diverter" magnetic configurations and the physical phenomena that occur at the interface between the hot plasma and the containment structure. The overall objective of these activities is to increase the duration of the plasma pulse in tokamak machines.

The CCMF has also been mandated to promote integration into the regional economy of all promising new leading-edge technologies developed in the course of the research.

Hydro-Québec's contributions to the CCMF include premises in its high-power laboratory, an experienced research team and various administrative support services, in addition to funding.

The TAI research team is active in four areas: management of the Centre; tokamak operation; development and operation of scientific diagnostics; and various theoretical studies.

Experimental contributions – Varennes tokamak

The initial series of experimental measurements that began with the production of the first plasma in March 1987 drew to a close in December 1988. During that time, the tokamak performance equalled or exceeded expectations and the scientific program consequently marked significant progress.

In January 1989, the tokamak was partly dismantled in order to install new components, including internal coils for creating a magnetic diverter configuration, other coils for rapid control of the horizontal position of the plasma, and a metallic (Inconel) liner between the plasma and the vacuum chamber. Also, a new electrical power supply was added for the horizontal-positioning control coils. The machine shop at IREQ was assigned the delicate task of producing the internal components, while the installation, dismantling and reassembly operations were undertaken by a team from the Service Réfections et Ingénierie. The tokamak is scheduled to go back into service during the first half of 1990.

Since the tokamak was out of operation the entire year, the TAI research team devoted its attention to analysing the results of the first series of measurements and to improving the performance of the diagnostics for which it is responsible. For example, the submillimetric interferometer was equipped with polarimeter channels for measuring the plasma current profile in the tokamak, a very important parameter but a difficult one to measure.

With regard to the imaging system used to study the soft x-rays emitted by the plasma, the two-dimensional tomographic reconstructions are of such high quality that now, for the first time, it is possible to choose between two incompatible ''sawtooth'' instability theories.

Significant modifications were made to the x-ray spectroscopy and Thomson scattering diagnostics to improve the quality, detail and efficiency of the measurements.

Theoretical contributions

Hydro-Québec's theoreticians form a large proportion of the CCMF's theory and interpretation group. The achievements of this group are underlined by its close collaboration with such research centres as MIT (United States), UKEA-Culham (England), University of Nancy and CEN-Caderache (France), which are working in the same field.

ITER Project

Among other activities in 1989, mention should be made of the Centre's first direct participation in ITER, a multinational project involving the design and construction of a fusion reactor. The four major partners are Europe, Japan, the United States and the USSR. Canada itself participates via the European program and, to a lesser extent, through the work it performs with the United States. Furthermore, the CCMF has seconded two senior researchers, including one from the TAI group, to work with the Next European Torus (NET) team at Garching, West Germany. NET is the cornerstone of European contributions to the ITER project.

Fusion
(Fusion)

NEW FACILITIES

The final stage in the construction of the new high-voltage underground cable test facility terminated this year and tests on the ±500-kV DC cable prototypes for the St. Lawrence River crossing was under way by the fall. Meanwhile, work began on the construction of an electric and magnetic field demonstration centre in the grounds of IREQ and plans were drawn up for a new mechanical test line to be built in the vicinity.

At the general laboratories, the new power system study and simulation centre is looking more complete as new equipment is installed and, lastly, the high-voltage laboratory has been fitted with a new hoisting bar for heavy apparatus.

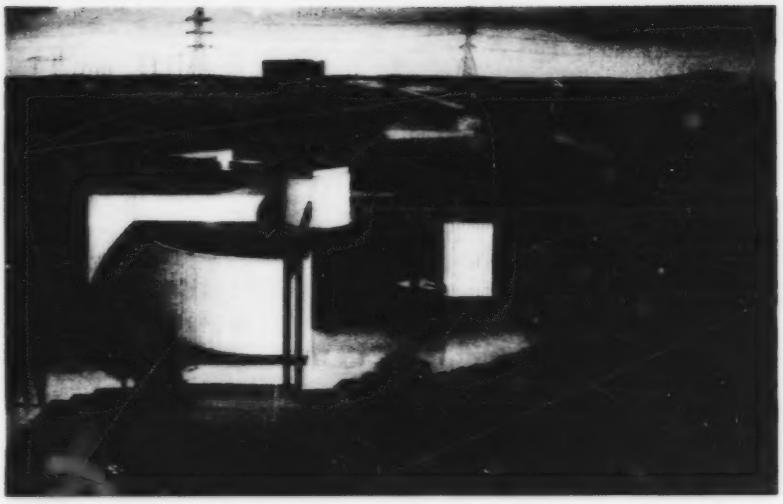
HIGH-VOLTAGE CABLE TESTING FACILITY

The new outdoor test area specially designed for studies on high-voltage underground cables was completed during the year. Hydro-Québec's Vice-présidence Équipements de production et Édifices was responsible for the construction work.

Tests on ±500-kV cable prototypes from three manufacturers began at the end of November as soon as the qualification and commissioning tests came to an end. The 11-month demonstration program is part of the project on the under-river crossing of the DC transmission line from James Bay. The aim of this test program is to check all the cable components and assess their long-term behavior under conditions simulating real operating conditions. (See article on this test program on p. 20.)

The test area is located between the high-voltage and high-power laboratories and has a total surface area of 20,000 m². It is equipped with a DC voltage source of 1.2 MV, 50 mA; a series resonant voltage source of 1.2 MV, 16 MVA; three current sources of 4 kA, 150 V, 60 Hz; and a 3.6-MV, 360-kJ impulse generator. These cable loops with their bushings and accessories can be installed simultaneously. The supply station has

The new high-voltage underground-cable test area seen through the mist one cold winter dawn.



The electric and magnetic field demonstration centre will welcome its first visitors in summer 1990.

the following specifications: 25 kV/600 V, 5 MVA. The control building with a surface area of 160 m² houses the measurement and acquisition system.

This testing facility will be used for future studies on even higher-voltage cables for 800-kV AC power systems.

Laboratoire Haute tension
(High-Voltage Laboratory)

CREATION OF AN ELECTRIC AND MAGNETIC FIELD DEMONSTRATION CENTRE

In accordance with its action plan on the effects of electric power lines, Hydro-Québec is building a demonstration centre in the grounds of its research institute, IREQ, in an aim to inform the public about the nature of electricity and the electric and magnetic fields produced by electrical apparatus. Located close to the 735-kV line running into Boucherville substation, the centre will offer visitors state-of-the-art knowledge on the biological effects of electric and magnetic fields. In this way, the utility hopes to address some of the public's concern about this poorly understood phenomenon. The official opening is scheduled for September 1990.

The 500-m² demonstration centre will have a multi-media room for films and animation together with an exhibition hall where various themes will be addressed: electricity in our daily lives (static, the magnetic compass, radio and TV interference); electricity as a natural phenomenon (lightning, the aurora borealis, neurotransmitters in the human body); electric fields (basic notions of electricity, atomic structure, charges, electric and magnetic fields); electricity and health (biological effects of electric and magnetic fields, research, medical applications of electricity).

The exhibitions will be interactive and visitors will be able to experiment with various electrical phenomena. They will also be invited to take a walk under the 735-kV line.

The technical committee in charge of this project comprises research scientists, environmentalists, health and safety experts, and information and public relations officers.

CONSTRUCTION OF A NEW MECHANICAL TEST LINE

A new mechanical test line is to be built near IREQ at a cost of $2.3 million. It will be used mainly to study the vibration of overhead conductors due to light winds since this type of vibration can influence the reliability of transmission and subtransmission systems. The new facility, scheduled to be operational early in 1991, will also be used to develop anti-vibration systems for dampers, spacers, etc.

The new 1.5-km line will comprise four towers of the same type as those used for the ±450-kV DC line from James Bay to New England. The line, which will not be energized, will be installed on a site swept by light-intensity and light-turbulence winds. Its location will be determined once the wind distribution studies are completed.

The existing mechanical test line in the Îles-de-la-Madeleine was built in 1973 to take advantage of the strong winds there. That line will not be dismantled but will continue to be used for long-duration studies such as fatigue testing, where on-site personnel are not required.

Mécanique
(Mechanical Engineering)

INSTALLATION OF A NEW HOISTING BAR IN THE HIGH-VOLTAGE LABORATORY

Early in 1989, a new 325-tonne hoisting bar was installed in the annex of the high-voltage laboratory where it is now used for handling heavy equipment such as power transformers and shunt reactors.

Compared to earlier equipment, the hoisting bar offers a far greater capacity and is easier to operate. Not only does it facilitate handling operations and reduce equipment assembly times, it improves working conditions and reduces the risk of accidents.

Laboratoire Haute tension
(High-Voltage Laboratory)

POWER SYSTEM STUDY AND SIMULATION CENTRE

Work continued throughout the year on completion of the new power system study and simulation centre. The staff began to move into their offices early in February and the simulation equipment was put into service in stages. By December the last components required for the 11th-line study – the Hydro-Québec and New England systems, the static compensators and control systems for the DC converters – were being tested.

However, the old simulator was kept in operation all year in order to meet the joint needs of the 11th-line study (James Bay – New England) and the series compensation studies. Also, the original design of the new simulator was revised in order to have two models of the Hydro-Québec system permanently available. The equipment was therefore reconfigured and plans were made to incorporate additional components. The latter are now being manufactured and the finishing touches should be complete by June 1990.

Études de réseaux
(Power System Studies)

A new 325-tonne-capacity hoisting bar was installed at the high-voltage laboratory.

MARKETING

Several agreements were signed in 1989 for the manufacture and marketing of products developed at Hydro-Québec and ten new licences were awarded. Among other products, mention should be made of the overhead-conductor vibration sensor and analyser, PAVICA; high-power-density resistances for air heating; a clamping system and a spacer-damper; a resistive-type voltage detector; and administrative and power system analysis software.

Twelve patents were obtained during the year for new products developed at IREQ laboratories.

MARKETING OF HYDRO-QUÉBEC SOFTWARE

The MECO software was officially launched in October 1989 by Strateck Technologies, an organization created specifically for marketing new administrative software. Developed by the utility's computer specialists, MECO is designed to automate the control functions of central computers.

Meanwhile, Hydro-Québec has signed a number of agreements with Cyme International, its subsidiary established to market power system analysis software. One agreement concerns the computer program MBRUIT, which determines the noise level and isophonic curves of noisy apparatus. Developed by studies and standardization experts in the Vice-présidence Équipement, MBRUIT went on the market in summer 1989.

The second agreement covers the "workstation" versions of the power system stability, short-circuit and power-flow software designed by IREQ's numerical-methods team. The same agreement also provides for the transfer of technical improvements to the revised "microcomputer" versions of these computer programs.

The third agreement is related to INIFI, a computer program designed by line hardware specialists of the Vice-présidence Équipement for calculating the bending of high-voltage transmission towers.

The constantly expanding volume of software marketed by Cyme has catapulted the small company to the top ranks of this type of software industry in America in less than four years.

Bureau de commercialisation
(Bureau of Marketing)

Photo : Cyme International

LICENCE AWARDED FOR A NEW ELECTRICAL TECHNOLOGY

This year Hydro-Québec awarded a licence with a capital-stock purchase option for the manufacture and marketing of a new electrotechnology: high-power-density resistances for air heating. The contract was signed on June 13 by marketing representatives from TAI and the firms of Pyradia and Intek, which have associated to form a new company for this project.

The new technology is the result of work on electrical resistance heating which was initiated at IREQ more than three years ago and transferred to LTEE early in 1988.

Compared to known technologies – open-coil and sheathed tubular elements – the new heating elements result in much smaller air-heating systems. They consist of perforated metal plates slotted together and assembled to form a block of electrical resistances. The element offers 10 to 15 times more power density than conventional technologies.

Bureau de commercialisation
(Bureau of Marketing)

Many software marketing agreements have been signed with Cyme International.

AGREEMENT TO MARKET PAVICA

On July 7, 1989, Hydro-Québec signed an agreement with the Québec firm Roctest to manufacture and market a device known as PAVICA, which is designed to sense and analyse wind-induced vibrations on overhead line conductors and to calculate their expected lifetime.

Developed by members of the Service Mécanique in cooperation with the Roctest engineers and IREQ's electronics team, PAVICA not only constitutes a precision measuring device but is equipped with its own microcomputer for on-site data processing.

A choice of several measurement scales is available and the duration of each measurement (1 to 12 s), as well as the time delay between measurements (1 to 255 min), can be programmed; the data are stored in a 64 x 64 matrix. The novelty of the new device remains its built-in microprocessor. The user can program the different test parameters using a terminal fitted with a standard RS-232 communication link. Whenever a reading is taken, the microprocessor compiles and processes the stored data again in order to calculate the current expected service life of the conductor under test. This calculation is based on the theory of cumulative damage in structures subjected to vibrations.

PAVICA's housing resembles that of the TVM-90 already marketed by Roctest and is interesting in that it can be installed directly on the conductor rather than below the suspension clamp. It can also be placed at any location along the conductor, near a spacer for example, and when the line is energized is simply installed with an insulating stick. PAVICA is lighter and more compact than any of its competitors and is designed to operate at temperatures ranging from –40°C to +70°C. Battery-powered, it can run for three months without intervention.

Bureau de commercialisation
(Bureau of Marketing)

LICENSING AND JOINT DEVELOPMENT PROJECTS WITH LYSTER INDUSTRIES

On October 16, 1989, Hydro-Québec and Lyster Industries signed an agreement to carry out joint development projects. The agreement, which also covers the awarding of licences, comprises two parts. The first is an eight-month project to develop a new nutcracker type of clamping system adaptable to all Hydro-Québec spacer-dampers; the total cost of this development amounts to $114,000. The second project, due to take 14 months at a total cost of $500,400, involves a new Hydro-Québec spacer for three-conductor bundles.

This is not the utility's first agreement with Lyster Industries: in July 1987, a manufacturing agreement and a marketing licence were signed regarding Hydro-Québec spacer-dampers for two- and four-conductor bundles.

Bureau de commercialisation
(Bureau of Marketing)

COLLABORATION WITH INDUSTRY

TAI executes R&D contracts and testing for external customers – electrical equipment manufacturers, engineering consultants, research centres and universities – and cooperates with them on many projects. The organizations and government agencies with which TAI has worked in the past year are listed below. Other details are given in the section International Activities describing the projects under way in over 25 countries.

ABB – ASEA Brown Boveri
ABB Power (U.S.)
AECL – Atomic Energy of Canada Limited
Agrinove
Alba
Alcan
Aluchem
Armstrong World Industries Canada
Automatec
B.C. Hydro
Bell Canada Entreprises
Bell-Northern Research
B.G. Checo
Bombardier
Boulangerie Doyon
CAE Electronics
Caisse de dépôt et placement du Québec

Preparation of a fatigue test on steel used for a penstock at Beauharnois 2 generating station.

Canada Wire and Cable
Canadian General Electric
Canadian Liquid Air
Canatom
CANDU Owners Group
CANMET - Canada Centre for Mineral & Energy Technology
Carrières Bedford
CDK Composites
CDNS - Centre de déshydratation Nord-Sud
CEA - Canadian Electrical Association
CEN - Caderache (France)
Chem Security
CIDA - Canadian International Development Agency
CIL
Circul-Aire
Consoltex
Coretech
CRIM - Centre de recherche informatique de Montréal
CRIQ - Centre de recherche industrielle du Québec
Culinar
Cyme International
Dettson
Ebonex Technologies (U.S.)
École Polytechnique de Montréal
Electricity Council Research Centre (U.K.)
Electrolyser
Electrosynthesis Company (U.S.)
Energy, Mines and Resources Canada
Environment Canada
Environment Ontario
Environnement Québec
EPRI - Electric Power Research Institute (U.S.)
ETS - École de technologie supérieure
Euratom
Fameca (France)
Federal Pioneer
Fednav
Fenco Lavalin/LGL
Ferranti-Packard Transformers
Fibro-Decor
Finisseurs de Montréal
FRDC - Food Research and Development Centre
Gaz Métropolitain
GEC Alsthom Énergie
GERAD - Groupe d'études et de recherche en analyse des décisions
Gradek Industrie
Hafner Fabrics of Canada
Hitachi (Japan)
Hydrogen Industry Council
ICI - Imperial Chemical Industries (U.K.)
Industrial Materials Research Institute
Industries FP
Industries 3R
Innovation technologique Intek
INRS - Institut national de la recherche scientifique, Université du Québec
Institut français du pétrole (France)
Jomac
Joslyn Canada
Kemtec Petrochemical Corporation
Lactancia
Los Angeles Department of Water & Power (U.S.)
Ludwig-Bölkow-Stiftung (West Germany)
Lyster Industries
McGill University
Malette Waferboard
Manitoba HVDC Research Centre
Manitoba Hydro
Maritime Electric
Maxtemp Thermo Confort
Melri
MIT - Massachusetts Institute of Technology (U.S.)
Montel
MPB Technologies
New Brunswick Electric Power Commission
Nova Scotia Power Commission
Ontario Hydro
PAPRICAN - Pulp and Paper Research Institute of Canada
Pirelli (Italy)
Pirelli Cables
Positron Industries
Powertech
Precarn Associates
Pyradia
QIT - Québec Iron and Titanium
Reichhold Limited
Research & Productivity Council of New Brunswick
Roctest
S & C Electric Company (U.S.)
Sandia Laboratories (U.S.)
Satexil
Siemens
Slater Steel
Snemo
Société de développement agro-alimentaire de la Mauricie
Sodexen
Stella
STK (Norway)
Stoody Delloro Stellite
Strateck Technologies
Supply and Services Canada
Syprotec
Tecrad
Thermonic
Trench Electric
UKAEA- Culham (U.K.)
Ultraoptec
Union Carbide (U.S.)
Unisys Canada
Université de Grenoble (France)
Université de Montréal
Université de Nancy (France)
Université de Sherbrooke
Université du Québec à Chicoutimi
Université du Québec à Trois-Rivières
Université Laval
University of St. Andrews (Scotland)
Vesta Technologies (U.S.)
Vibro-Meter
Volta Énergie
W.R. Grace (U.S.)
Zagram Canada

INTERNATIONAL ACTIVITIES

Hydro-Québec International continued to promote and market Hydro-Québec's expertise as an electrical utility in 1989. Work was initiated or pursued on projects in some 25 countries in Africa, Asia and South America. New this year were a number of studies on multinational power system interconnections.

AFRICA

Cameroon

Collaboration with Cameroon's national electricity company, SONEL, continued this year in the form of the comprehensive training and technical assistance program set up several years ago. Some 15 Hydro-Québec specialists in various areas of the electrical utility industry are now working at SONEL under agreements to provide cooperation and institutional support. The training program for SONEL technicians and managers this year again took the form of courses at Québec educational institutions and training sessions in various departments at Hydro-Québec.

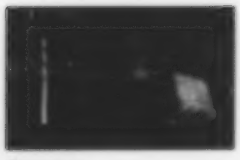
Meanwhile, work was completed on the development study for the Nachtigal project, which involves the construction of a 260-MW generating station on the Sanaga River.

Ivory Coast

Two Hydro-Québec specialists were seconded for two years to government agencies in the Ivory Coast, the first to act as advisor on accounting and financial matters to the national electrical utility, the second, a distribution engineer, to work with the utility's major projects supervisors. Another Hydro-Québec specialist has been in the Ivory Coast since 1987, acting as advisor responsible for follow-up in the energy sector for the Department of Industry and Planning.

Egypt

Six managers and engineers from the national electrical utility came to Hydro-Québec for training sessions in power system control. The training sessions are part of an Ontario Hydro project involving the creation of a power system control centre in Cairo.



Cameroon

Ivory Coast

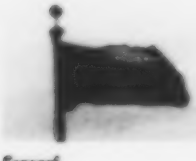
Egypt

Gabon

Madagascar

Mali

Morocco



Senegal

Guinea

Two Hydro-Québec experts in data processing and accounting spent time in Guinea this year to meet a specific need expressed by that country's national electrical utility, ENELGUI.

Madagascar

In the framework of a planning study launched in 1988, Hydro-Québec personnel has performed rates studies as well as a comprehensive technical assistance and training program for the government-owned utility. The aim of this project is to establish an initial minimum-cost expansion plan for the country's generating and transmission systems. Technical assistance will continue until spring 1990.

Togo

Zaire

Mauritania

Mali

Hydro-Québec International, in a consortium formed with Tractebel, has been supervising the construction of a 150-kV line between Bamako and Ségou. Work began this year on the 230-km line which will constitute one of the main arteries of Mali's electric grid and will supply a number of 15-kV and 30-kV medium-voltage networks. The engineering studies were completed in 1988, four years after they began.

Meanwhile, an expert in procurement in a utility environment has been seconded to Mali's national electricity company, EDM.

Morocco

Work was completed in 1989 on the preliminary studies initiated last year for the construction of a mini-hydroelectric generating station near a village in the Atlas mountains and the construction of rural distribution lines for some 50 Moroccan villages.

Senegal

Two of the three Hydro-Québec specialists seconded to Senegal's government-owned utility in 1987 continue to act as technical advisors on the operation of generating, transmission and distribution facilities and on financial management and customer accounting. The training program for Senegalese personnel continued, both in Québec and Senegal, while work which began in 1988 on a feasibility study on the proposed national dispatching centre was completed during the year.

Togo

Hydro-Québec International performed an assessment of Lomé's distribution system in 1989 and a stock management and procurement specialist has been seconded to the national electrical utility for a two-year period.

Zaire

Upon completion of the stability studies Hydro-Québec International had been conducting for the past six years, work began on the detailed engineering studies for rehabilitation of the N'Zilo dam. The training program launched in 1988 for engineers and technicians at the government-owned utility drew to its close in the course of the year.

Development of the Senegal River

1989 saw completion of Hydro-Québec International's feasibility study of the transmission line to carry power from Manantali generating station to Senegal, Mali and Mauritania, the three member countries of the organization responsible for the development of the Senegal River. This study is being carried out in collaboration with Tractebel and ÉDF International.

ASIA

AUSTRALIA

A study of the dynamic performance of two static compensators built by Siemens for Kemp Creek substation in New South Wales was performed in 1989. The study, which took three months, involved tests on the new power system simulator at IREQ.

KOREA

Three members of TAI's research staff have carried out a study of a synthetic test circuit design for the Korean Electrotechnology Research Institute, KERI. Working in close collaboration with Daewoo Engineering, the Korean firm responsible for the detailed engineering aspects of the project, the research team contributed the fruits of IREQ's 10-year experience with the synthetic test circuit in its own high-power laboratory. KERI is particularly interested in the multi-stage design of the synthetic circuit, the transient-recovery-voltage control technique and the laser-triggered firing system used for the spark gaps.

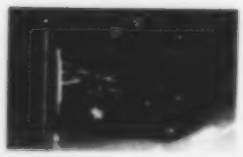
Multi-stage circuits have many advantages for high-voltage facilities such as KERI's since they reduce the space requirements and construction costs of the test hall.

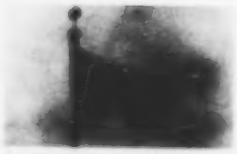
INDIA

HQI came to the assistance of Bharat Heavy Electric when this Indian company encountered a problem with the installation of compensation equipment intended for a steel plant that the Hindustan Development Corporation plans to build in Gwalior.

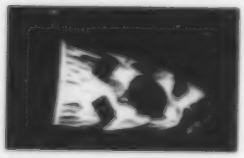
In other projects, TAI's power system studies specialists continued to collaborate on a special research and development project approved by the Indian Planning Commission. The aim of this project is to build up the government-owned utility's expertise in HVDC system design, installation and operation. The utility has now begun to build an experimental HVDC link some 200 km long. HQI not only took part in the commissioning of the first phase of the project, which was terminated in October 1989, and the design of phases 2 and 3, it also delegated representatives to attend a seminar on high-voltage transmission organized by the Central Board of Irrigation and Power in New Delhi.

Lastly, help was given to the Indian government in the implementation of its future 800-kV nation-wide power system and the creation of a new National Power Transmission Corporation.

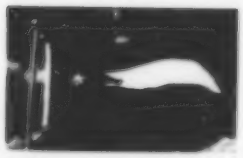

Australia


People's Republic of China

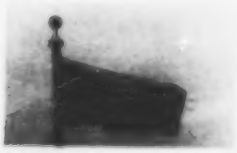
Iraq


Korea

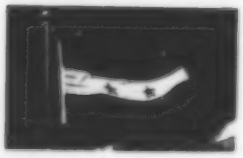
Venezuela


Jordan

India


Colombia

Turkey


Syria

People's Republic Of China

Hydro-Québec continued to provide technical assistance to the various electrical research institutes in this country. Several Chinese engineers and specialists came to Québec to participate in training sessions in areas related to simulation, remote control, remote protection and conductor vibration.

Supplementary studies for the Three Gorges project continued in an attempt to explore in depth some of the aspects already investigated.

SOUTH AMERICA

Colombia

A specialist in the civil engineering of dams continues to work actively on an international committee of experts set up by Empresas de Energía Eléctrica de Bogotá (EEEB) to follow up on the Guavio project. This project involves a hydroelectric generating station and two 100-km 230-kV transmission lines.

Venezuela

In collaboration with the firm RSW, technical assistance was provided to Electrificación del Caroní in the engineering, management, operation and maintenance of its high-voltage transmission lines and related substations.

This assistance covered various aspects ranging from substation voltage selection methods and calculations to event and equipment-failure diagnostics. In addition, a standard approach was proposed for designing electrical facilities and selecting appropriate equipment.

MULTINATIONAL ELECTRICAL INTERCONNECTIONS

Egypt-Turkey

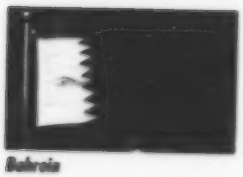
A joint study with Ontario Hydro on the interconnection of power systems owned by Egypt, Iraq, Jordan, Syria and Turkey began this year. Amman in Jordan has been chosen as the headquarters for the agency formed by these countries to handle the management of this study.

Arab Peninsula

Work has begun on a study of the interconnection of power systems operated by six Gulf countries: Bahrein, headquarters of the Study Committee, Kuweit, Saudi Arabia, Qatar, Oman and the United Arab Emirates.

Zaire-Egypt

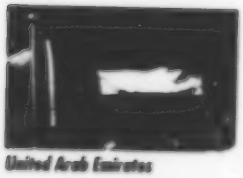
Two Hydro-Québec specialists have already drawn up the terms of a mandate for a Zaire-Egypt interconnection study.



Bahrein

Qatar

Kuwait



United Arab Emirates

Oman

Saudi Arabia

São Tomé and Principe

ACTIVITIES RELATED TO THE FRANCOPHONE SUMMIT

Various activities took place this year under the auspices of Hydro-Québec's cooperation and training program for electrical utilities, which was launched in September 1987 at the request of the Québec government. The objective is to make Hydro-Québec's technological expertise and administrative know-how available to other utilities to help them meet their needs in fields such as power system planning, operation and management. Hydro-Québec has earmarked $5 million for this five-year program, which is managed by HQI.

A number of training and cooperation projects have been carried out in various French-speaking countries in Africa in 1989:

- development of a master plan for the energy sector, for São Tomé and Principe in the Gulf of Guinea.
- preparation of a training plan for employees of Senegal's national electricity company, Sénélec, and completion of a similar plan for Togo's government-owned utility, CEET.
- two seminars, one given in Senegal, the other in Mali, on grounding practices used on North American distribution systems;
- start of work on a film about Cameroon's national utility, SONEL;
- training sessions at Hydro-Québec for nine senior-management representatives from EDM in Mali.

AWARDS AND DISTINCTIONS

National and international awards were bestowed on several TAI staff members in 1989.

IEEE – Montréal Section

Michel Duval, researcher, Service Chimie des matériaux, was elected Chairman of the Montréal Section of the IEEE for a one-year term. The section comprises some 2000 members.

MICA Award

The Conseil de l'industrie électronique du Québec awarded a MICA award in the large-corporations category to François Morin, researcher, Service Chimie des matériaux, for the microhmmeter he has developed.

This instrument is designed to measure extremely low electrical resistances in connectors exposed to very high currents. It is now being used to calculate sleeve misalignment on 735-kV cables and to check new joints in generating units at the power plant.

Morris E. Leeds Award

Ryszard Malewski, researcher, Service Mesure et Informatique, has won the IEEE Morris E. Leeds award for his outstanding contribution to high-power and high-voltage precision measuring techniques. This distinction was awarded in recognition of the many technical and scientific papers he has published and the patents he has obtained.

Michel Duval

Ryszard Malewski

François Morin

R&D 100 Award

The American magazine Research & Development selected IRECA steel as one of the most innovative products in its annual R&D 100 competition. This product was developed by a team from the Service Technologie des matériaux: Raynald Simoneau, researcher, responsible for materials characterization and development; Jean-Luc Fihey, researcher; and Tony DiVincenzo and Jacques Larouche, technicians.

IRECA steel is a high-strength material used to repair turbine runners damaged by erosive cavitation. It is marketed under the tradename Hydroloy HQ 913 by Stoody Delloro Stellite, which has signed a licensing agreement with Hydro-Québec.

Royal Society of Canada

The Royal Society of Canada awarded its Thomas W. Eadie medal to Ashok K. Vijh, research fellow, Vice-présidence Recherche, in recognition of his major contributions to engineering and the applied sciences. Dr. Vijh is known throughout the world for his achievements in electrochemistry and electrochemical physics.

(from l. to r.) Jacques Larouche, Jean-Luc Fihey, Tony DiVincenzo and Raynald Simoneau

Ashok K. Vijh

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